Development of an energy saving product for use in the kitchen

Based on the working principle of hay boxes for use with modern kitchen pots

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Development Of An Energy Saving Product For Use In The Kitchen

Based on the working principle of hay boxes for use with modern kitchen pots

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Summary

The exercise of this Bachelor thesis was to develop a passive cooking device to cook the food, after heating it up once in a normal pan or pressure pot. There the cooking process in continues by using insulation. The device will be sold together with an application for mobile devices. The device is developed to be first sold on the Dutch market and later on the European market, and is designed for ComfortSavers situated in Middelburg, Zeeland. The company is just starting up and wants to develop energy-saving, ecological friendly and recyclable products that go along with modern trends. The resulting device is named “CookSaver”.

The idea of cooking in insulation is very old. As the market and trend research showed, there is no product available which fits to every pot or pan, and can be bought as an independent product. The CookSaver is most interesting for young families with children, young couples as early majority and for elderly people who know the principle and want maintain traditions as late majority.
As the payback time for the user should not be longer than two years the device costs around 50€. The time savings while using the device are 60% and it can be kept warm 186 minutes until the critical food temperature is reached of 60°C.

The final product is made of recyclable ABS,d PC (Polycabonat) and Lumira®Aerogel particles, a special kind of aerogel, which are labeled “Cradle to Cradle”. The colors are black, green and blue are orientated at the Cradle to Cradle principle. The product shall mainly be produced by injection molding and some parts need to be bought in externally.
The final performance is tested with a prototype. The prototype was made as close as possible to the final product. So, it proofed the assumptions made for a theoretical calculation and can be used very well for testing purposes.

Samenvatting

In deze bacheloropdracht is een passief keukenproduct ontwikkeld dat eten in geïsoleerde toestand gaar kan laten worden nadat het met een normale of drukpan is het product, vanaf nu “CookSaver” genoemd, zal in combinatie met een applicatie voor mobiele apparaten op de markt wordt gezet. De CookSaver is in eerste instantie voor de Nederlandse en daarnaast voor de Europese markt ontwikkeld. Het is ontworpen in opdracht van het bedrijf “ComfortSavers” gevestigd in Middelburg, Zeeland. Het bedrijf is recentelijk gestart en wil energiebesparende, milieuvriendelijke en recyclebare producten ontwikkelen die bij de laatste trends passen.

Het idee om voedsel te bereiden middels isolatie bestaat al lang. Echter bestaan er volgens markt- en trendonderzoek nog geen producten die met iedere pan gecombineerd kunnen worden. Vooral jonge families met kinderen en jonge stellen vormen een goede doelgroep voor de CookSaver. Deze worden beschouwd als de eerste klanten omdat deze ervan bewust zijn dat het nodig is energie te besparen en tegelijk graag trends willen volgen en met moderne apparatuur kunnen omgaan. Op een later tijdstip kan het product ook voor ouderen interessant zijn omdat deze graag tradities levend houden.

De prijs van het product is circa € 50 omdat de terugverdientijd voor de gebruiker niet langer dan 2 jaar zou mogen zijn. Er kan 60% tijd bespaard worden t.o.v. koken zonde isolatie en het eten kan voor 186 minuten warm gehouden worden tot de kritische temperatuur van 60 graden bereikt is.

Het eindconcept is gemaakt van recyclebaar ABS , PC (Polycarbonate) en Lumira® Aerogel deeltjes. Dit is een bijzondere vorm van aerogel welke “Cradle to Cradle” gecertificeerd is. De kleuren zijn zwart, groen en blauw. en refererend naar het Cradle to Cradle principe. Het product kan grotendeels geproduceerd worden door middel van spuitgieten en een aantal apart in te kopen onderdelen.
De finale prestatie is met behulp van een prototype getest. Deze was zo dicht mogelijk bij het echte ontwerp gemaakt. De metingen welke uitgevoerd zijn met de prototype hebben laten zijn dat de aannames in de theoretische berekeningen erg realistisch zijn en de prototype goed voor testen gebruikt kan worden.

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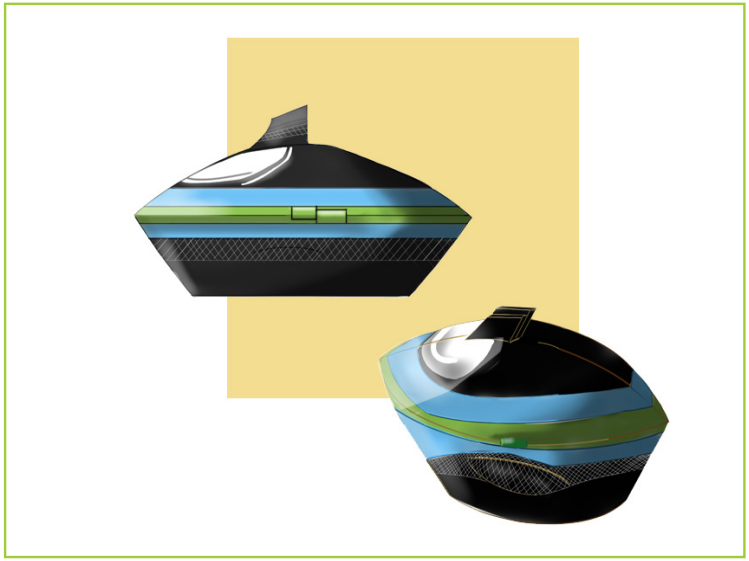


Content

1. Introduction

The following report is written as Bachelor thesis for the study Industrial Design of the University of Twente and carried out for the Company "ComfortSavers" located in Middelburg, The Netherlands. The company is just starting up and aims to develop and sell energy saving, eco-friendly, green products which are also considered to be modern and orientated towards trends. At the moment several students at the UT and the University of Delft develop products for the company. The first products shall be launched at the begin of the year 2014 and be produced by companies located closed to Middelburg

The aim of the Bachelor thesis was to develop a passive cooking device to cook food in insulation, after it was heated up in a normal or pressure pot. The device, later called the "CookSaver", is sold together with an app . Hence, the goal of this exercise is to develop the CookSaver for safe cooking of single ingredient meals and create an interface with the app. The result will be a prototype based on a 3D model to test the CookSaver and give recommendations. The prorotype shall be as close as possible to the final product.
Considering the constant increase of the energy price and the limited resources of fossil fuels it will be necessary to save energy. The CookSaver is considered to go along with this development.
Based on the definition of the target group information about their cooking behavior is obtained through a survey and research. A "cooking profile" is set up to definite possible energy savings and at the same time money savings.
Furthermore, a preliminary market research is performed and the various options for insulating material are investigated. This report informs about the requirements that such a product needs to fullfill and how it can be realized regarding these requirements.

To obtain a list of requirements the report starts with an analysis. The first paragraphs of chapter 2 answer the question to which target group the product is most interesting. A survey follows which gives more information about the just determined target group and which the key drivers for purchasing a new kitchen product are. The reader is also informed about the cooking behavior of the target group.
Secondly, research is done about trends on the market, competitor/comparable products and well-insulating materials.
This part of the analysis adds requirements about how the device can look like and which materials are suitable. Besides, an energy saving analysis is performed to give an answer to the questions how much time and how much money can be saved to estimate the maximum price of the CookSaver. The result of the total analysis is a list of requirements and wishes, which is used for the concept development.

Within the concept development, to be found in chapter 3, three different concepts are developed which look and function differently. Finally these concepts are compared with the requirements and evaluated according to their feasibility and attractiveness for the target group.

The chosen concept is detailed and its healthy appearance, usability and structure are improved. Chapter 4 gives insight how the basis concept is further developed regarding its appearance, structure and performance. Also the manufacturability and costs are considered in this chapter. The last paragraph of this chapter represents a 3D model, costs and how the mass productions of the product could look like. Based on the 3D model a prototype is made a short interface analysis and an interface set up can be found in chapter 5 which connects the CookSaver with the future app.

The last two chapters, 6 and 7, inform about performance tests with the prototype and give recommendations for further development.

The Appendix are included partly at the end of the report and partly on a CD. A pre-fix indicates where the Appendix can be found. For example Appendix P-X can be found on paper and Appendix CD-Z on the CD.

2. Analysis

An analysis in performed in order to obtain important information about the target group, the market, competitors and cooking related aspects such as legal framework, safety and cooking times of hay boxes. To gather information which cannot be found in books, from Internet or asking experts a survey was done. A list of requirements and wishes will be the result. At least a material analysis is done before the start of the design process. It resulted from a line of thoughts together with ComfortSavers who would like to see if there is the possibility to base the concept on certain materials.

2.1 Historical background

First, a short look at the history seems helpful to find out whether the idea about cooking in insulation is actually new or has been realized in the past. As a consequence there could be users who already know the concept and are interested in it, existing patents have to be considered or things learned from experience.

Figure 2.1: "Backautomat" Heinzelmänchen

At the first glance, it seems that the idea is not new. The first annotations about how to construct a device to cook in insulation are dated to the French-German war in 1870-1871. Most of these annotations where construction plans how to build them with simple materials located in every household. They were called "hay boxes" as hay or straw was commonly used to insulate the cooking pots. Every time there was a lack of energy people re-discovered hay boxes to save energy.

Figure 2.2: Wool and hay filled cooking bag

In 1916 the first commercial hay boxes were sold. The most popular model, called "Koch-, Brat- und Backautomat Heinzelmännchen" (Figure 2.1) was a box of wood, which was filled with hot stones, to stretch the cooling process. Together with the "Backautomat" a cooking book was sold with recipes adjusted to the special requirements of the device. It was promoted with cooking without fire, energy saving and safety. Figure 2.2 demonstrates a different, home-made model. It is a pillowcase filled with wool and called "cooking bag".
There are several books, written around 1900, which describe how to build a hay box and/or recipes[2.1] . A short review of the cooking books informs about average cooking times. It costs a lot of time to prepare one entire meal in one pot. Some recipes take 12 hours until food is ready. In comparison single ingredient meals, such as only potatoes or only vegetables, are cooked quite faster. In average, it takes between 20 and 40 minutes, depending on the size of the pieces to be cooked.
As time passed by and economic wealth increased, hey boxes were forgotten and considered less useful due to their mostly long cooking times. Only some comparable devices as slow cooker still exist as a follow up to hay boxes. They do not save much energy and are not insulated well but are fine for some purposes.
Since a few years, a new movement of LoHa's (a group of people which identify themselves with the slogan: "Life Of Health and Sustainability") recovered hay boxes or thermo cookers, as they are called now. Their thermal cookers are still made of common materials, but they adjusted them to their special needs. They could form a possible target group as well as older people who are familiar with the concept.

2.2 Target group analysis

The target group of the future kitchen device was not entirely determined at the beginning of the project. Based on the history review, several possible target groups are identified. They can be divided into three groups:

I. Elderly people who are familiar with the concept
II. People who need to save energy out of financial reasons:
    a) First world
    b) developing countries/countries with a poor infrastructure (as after the 2nd world war)
III. People who consider sustainability as a life style choice.

Regarding the conditions of ComfortSavers a first choice of the target group can be made. It is assumed that the people belonging to group II cannot purchase the CookSaver and smart devices and the Internet are not sufficiently accessible for them. Hence, an attractive target group is younger people, with and without children who are aware of the need to save energy. They are considered as the early adopters and early majority[2.2].
As second target group, elderly people are interesting to consider as they have time, experience and want to maintain traditions. Maybe they are not as familiar as younger people with smart devices, but they are also able to purchase the CookSaver and realize its benefits. They are considered as late majority.
The focus of the following paragraphs lies on the main target group of young people and provides a theoretical background as they are of main interest.

2.1 E.g: "The farm and home cook book and housekeepers assistance" ,Adeline Goessling (1907)
2.2 Eger, A. , Bonnem, M., Lutters, E. Van der Voort, M. "Productontwerpen" (2010), Den haag Boom/Lemma

2.2.1 Description of the target group

The primary target group is yet defined and described for the US market. There are people who are generally interested in “green” products called “LOHAS®” which stands for “Life Of Health and Sustainability”. The expression quantifies the “market segment for socially and environmentally responsible products and services” (Natural Market Institute [NMI], US, 2011)[2.3]
The NMI has established a scheme to classify customers respectively to their topic of interest and level of commitment to ecological and sustainability aspects. The NMI subdivided users basically into five eco-personality types which are further defined by the depth of insight into a certain topic (figure 2.3).
At this point the scheme is used to determine characteristics of the target group and get inside into the key drives for purchasing a new product.

Figure 2.3: NMI scheme

As the groups are not static, not only the group of LOHA®, but also “Naturalities”®, “Drifters®” and “Conventionals®” are targeted for the CookSaver. Unconcerneds® are totally not interested in environmental or social advantages of products. Which means there remain four “sub-target” groups which have the following characteristics in common:

1. Personal health
2. Interest in “green products”
3. Want to do something to protect the environment

Left, figure 2.4 : Collage of families
Right, figure 2.5 : Collage of young people

4. Socially responsibility
5. Cost savings
6. Want new products
7. Want easy lifestyle

The first 5 aspects agree with the goal of ComforSavers for the CookSaver. Aspect 6 and 7 add information about the target group and probably agrees with young people. A survey proofed that the scheme also can be applied to the European market. The next paragraph “collage” relates and compares the numbered characteristics with the pre-determined target group.

Collage:
It is always easier to imagine a target group with some pictures. Further differences and coincidences of having or not having children are pointed out. Hence, two collages are made and compared (Figure 2.4 and 2.5). The topic “outside activities” is a little special but as environmental issues play an important role, the user in the “environment of nature”, and not only in the environment of the kitchen, is considered.
First, it can be stated that health and sporting outside is very important, so a healthy appearance is demanded. Families do it with children and adjust the kind of sports to their abilities and couples enjoy it together. Where families enjoy to picnic outside, young couples like going out with friends and have a drink. If the future kitchen would be portable outside the house it was a nice accessory for families.

2.3: The NMI is an institute who does research for companies. Partially their results are open to the public. For detailed information visit http://www.nmisolutions.com/(16-04-2013), source scheme: (source: http://eco-flu ence.com/life-cycle-of-an-environmentalist/370/, 16-04-2013, Adam Hammes, Sustainability Manager

Investigating the typical kitchens it can be observed that there are also a few distinctions. The kitchen of a household with children is a little messy and children like to participate in cooking. It is taken into account that children certainly will come in contact with the CookSaver which means it needs to be child-proof: It may not be opened easily, or prone to tumbling. Due to the insulating effect the device will not become hot and is by definition already safer than a normal pot. Furthermore, over-cooking, mouth burning or short circuits are less probable.
In contrast, the kitchen of couples is clean and well-arranged. Couples communicate while cooking with each other and enjoy cooking (and eating). The usage of cooking books or even a computer during preparation of the meal is very common as there is less danger of damaging them without children. This indicates interest in gadgets and modern technologies. If the use and the design of the device reminds of a gadget, it is an advantage. Furthermore an advantage was if the device was easy and fast to clean or could be placed in the dishwasher.

Looking at the use of smart devices (mobile phone, tablet), it can be seen on both collages that there is a social component. Men talk about it and use it frequently. Parents show their children how to use it and use it together. Children play with it and couples use it to obtain information. The use is very broad but in anyway attractive to all young people. Due to the social component, data should be sent or received by more than one device at the same time.

How these two sub-target groups spent their spare time differs also. In either way, there is not so much information found related to the design of the kitchen device.

2.2.2 Definition of the target group

After the review, the following definition of the target group was set:

The primary target group of the CookSaver, consists of young working people and families with young children. They have learned a profession; have a job and a middle or high level salary. They are aware of the need to save energy and are familiar with and appreciate the use of smart devices. General health and an easy and modern lifestyle play a very important role in their life. The secondary target group is seniors who have experience with hay boxes and have a regular or middle high retirement pay who still live at home.

2.2.3 Summary

The principle of hay boxes is very old. There are few people still using them, since with the current economic wealth they are forgotten and obsolete in their original form. Original cooking recipes for hay box prepared food can still be found and are of great interest. They consist of recipes and cooking times for single ingredient food to an entire meal.

The target group is determined to be young families as their requirements have a lot in common with the ones of ComfortSavers. Characteristics are well-educated, middle to high salary, well-informed, active, health aware and socially orientated. Cooking is a social event which is enjoyed with the family, children, friends and the partner. Experiences are shared by using smart devices.
To them the CookSaver not only needs to save energy but also be economic friendly and socially responsible produced as well as being recyclable. A healthy appearance should be found as health is an important topic to the target group. Besides, it is very important to communicate the energy and time savings as especially young people consider energy saving as a personal achievement in lifestyle considering their way of life.
To families safety plays an important role and needs to be considered during the concept development. The extra safety for children needs to be underlined: There is one pot less in the kitchen where they can burn hands.
Further a gadget-like appearance is an advantage to communicate easy and modern lifestyle by using the product.

It will also be considered to make it portable or, at least easily moveable due to the active habits of the target group. The survey will add information about the place of the kitchen device and if it desirable.

Very superficial elderly people are mentioned as secondary target group. To them the main key drivers for buying the CookSaver are maintaining traditions and the special taste of the food. At a later point it is of interest to design the device to be easily adjusted to a non-smart variation for an elderly, but wealthy target group is decided together with ComfortSavers.

Some aspects will need further research: The daily cooking behavior of the target group and, besides safety, health and hygiene restrictions for the food. The importance of the numbered characteristics shall be evaluated in the survey to show important for the customers on the European market and specify the demands of the target group.

2.2 The survey

The survey had two different aims. One is to get insight into the cooking behavior of the target group, their design preferences and most valuated key drivers for purchasing a new kitchen product. Also a few questions are asked about the use of smart devices. The answers to these questions are evaluated in chapter 5.

The second goal was to proof some assumptions and conclusions made during the target group analysis: An existing relation between age and use of smart devices, level of education and health importance, salary and purchasing ability and finally age and knowledge over hay boxes.

The next paragraph sums the results up and further they are evaluated respectively to their significance for the CookSaver. At last, the limitations of the survey are pointed out.

A complete list of all questions as well as all answers can be found in Appendix CD-A.

2.3.1 Summary and evaluation important results

First, the general data are evaluated. The statistics are based on 62 completed, valuable surveys. Table 2.1 up to table 2.5 presents the general data.

Female	Male
57%	53%

Table 2.1: Gender

<18	18-25	25-45	45-65	>65
0.0%	79.4%	17.5%	3.2%	0.0%

Table 2.2: Age

Secondary education	Vocational profession	Bachelor	Master	PhD	Other
22.2%	3.2%	57.1%	11.1%	1.6%	4.8%

Table 2.3: Education

Having children	Not having children
6%	94%

Table 2.4: Having children

Low	Middle	High
79.4%	12.5%	6.3%

Table 2.5: Salary

A good ratio of gender respondents is reached and of the educational background is reached. However, from the distribution of “Age”, “Earnings” and “Children”, it is obvious that the respondents do not fit entirely within the target group. The majority earns less than expected and has no children; therefore any kind of data related with possible purchasing of the product will not be reliable. It is supposed that if the customer has a higher income, he is more likely to purchase a new kitchen device which is not indispensable. Furthermore, the frequency of cooking probably varies between having and not having children as well as the importance of different cooking aspects. However, young people with a higher educational background still form a part of the target group. The survey will at least pictures mainly and behaviors.

Eating behavior and cooking behavior. The second step is to look at the eating behavior of the consumers to receive information about the food to be prepared and how long it takes to prepare it. The data of the survey draws the following picture of the average, young customer:

They cook approximately 30 minutes every two days for 2 a 4 persons and use most of the time 2 pots to prepare a meal. The majority (78.5%) considers themselves as an average cook. The target group cooks varied vegetables, meat or just vegetarian. Sometimes they use instead of pots an oven for cooking.

Consequently, some restrictions for the CookSaver can be pointed out. Related to the number of “eaters” the size of the used pots can be estimated and so the expected dimensions of the CookSaver. A short research is done before the concept development (Chapter 3). Further it comes up that the CookSaver should be flexible in size to fit with every pot and needs to be easy to handle for an average experienced cook. As mostly several pots are used, it is an advantage if the CookSaver can insulate multiple pots at the same time, if necessary. Yet, it would rather be a wish than a requirement.

In any case, the customer cooks varied and any kind of food should be prepared safe.

Yes	Sometimes	No
66.7%	31.7%	1.6%

Table 2.6: Healthy cooking

Additionally in paragraph 2.5, the numbered data is used to estimate possible energy and costs savings by cooking in insulation.

Also of interest is the importance of healthy cooking to the target group. The target group analysis pointed a high importance out and compared with the values of table 2.6 it can be stated as proofed.

To connect with the needs of the target group the CookSaver should have a healthy appereance which reflects the awareness towards healthy cooking.

To estimate other values related to cooking, the lifestyle characteristics from the NMI scheme had to be valued (Table 2. 7). It is noo difference made between the four eco-personalities as they are considered to form together the target group.

Aspect:	Health	Taste	Like	Relaxing cooking	Sociable
Average value:	4.02	4.6	3.63	3.00	4.29

Table 2.7: Valued aspects of the NMI scheme (1=very low, 5= very high)

Health, taste and sociability play an important role. It means that in a cooking process, more than one person could be involved. To prevent confusing the CookSaver should be able to send data to more than one smart device at the same time. The aspects of how to cook and that cooking is relaxing are less important. It is not necessary to consider them in a special way.
Besides, the high values indicate that the characteristics are not only valuable vor the U.S., but also the European market.

About the respondents with children is little to say as there are only 4 of them. So far, all of them cook less than 20 minutes, they use more the oven and they cook nearly daily. Therefore it is assumed twice a week an oven is used instead of the stove. This choice will influence the energy and money saving calculations.
The number of pots and the number of people to cook for with and without children does not show any special dissimilarity.

Place in the kitchen. Another aspect of the survey was to determine the place of the future kitchen device in the kitchen. This will deliver constraints for dimensions but also functionality. ComfortSavers expressed the wish to develop a product to set on the sideboard to increase its publicity.
Regarding to the survey. the main key factor to set a product on the sideboard is its functionality. In first instance, people think about to place it in the cupboard (43.5%) and secondly to set on the sideboard (38.7%). The aim should be a designed product that persuades the user with its functionality to set it on the sideboard.

While cooking, the user wants to place the CookSaver a little aside where it does not disturb the further cooking. While eating, most of the respondents want it still in the kitchen or on the dining table. The kitchen device should therefore be easily portable within short distances and not have an uncommonly high weight. The CookSaver should not extend much the dimensions of a normal pot; otherwise it would be difficult to handle. It should also be easy to clean, because in the kitchen and on a dining table, it probably will come in contact with food and liquids. Hence, the material, it is made of, should be resistant to cleaning supplies.

Purchasing factors: The next step was to look at the key drivers to purchase a new product and implement them into product requirements.
In table 2.8 the different aspects are numbered why to buy a new, energy saving product:

Aspect	Personal health	Green product	Socially responsible	Like gadgets	Cost savings	Easier cooking	Better enviroment
Value	3.29	3.26	3.03	2.82	3.76	3.39	3.23

Table 2.8: Purchasing factors for an energy saving product (1=very low, 5= very high)

Again, these values show that health plays an important role, but even more important are costs savings and easier cooking to the respondents. The green products and environmental influence seem to form a good addition. Apparently an energy saving product is not seen as a gadget regarding its low value.

The same results come from the comparison of the questions if someone would buy a kitchen device if it was healthier, better tasting or energy saving.
Under the condition having children, the results do not differs; so far the conclusion can be taken from the low number of respondents.
At last different types of products are compared towards their attractiveness to customers:

Product				
Score	2.76	3.27	3.03	1.82

Table 2.9: Different kitchen products sorted by design aspects (1=very low, 5= very high)

About the different types of a product, it should be stated that the ones only made of plastic or only made of wood are least appealing. It seems the use of wood is acceptable if it is used with another, modern material. Apparently, contrasting materials in kitchen products makes them more interesting and appealing whereas the material itself plays a minor role. So, the CookSaver should also be made of contrasting materials.

Other information of the users: It is also asked in which kind of other information the users would be interested. Most of them are not relevant for the design but for the app and are evaluated in chapter 5. The ones which are relevant at this point are already mentioned.

Assumptions: At the beginning, some assumptions were made, now a look is taken if they can be affirmed.
First, it can be stated that the evaluation of the answers under a certain condition was difficult. The distribution of respondents is very unequally with respect to age, salary and education. Consequently, most of the assumptions could not be affirmed nor disproved. There is neither a notable correlation between education and awareness towards health and energy saving topics nor one with income. The only outstanding is parameter is that the respondents with middle income state that they prefer to buy an energy saving product and a healthier device. As health and energy savings are valued important for all the respondents, independent on age or education, they remain part of the target group definition.

2.4 Market analysis

There are different reasons to take a look at the market. First, it needs to be found out if there are similar products to compete with, which may not be copied or to learn something of.
Second, a requirement of ComfortSavers for the CookSaver was to be trend oriented and fit within a modern kitchen. This section shows what the trends are and how they can be translated into design requirements and implemented in the future design.

2.4.1 Comparable products

The market analysis started with an internet and catalogue (e.g. Ikea, Schöner Wohnen) based research of competitor products. The outcome is presented in table 10. There are four interesting competitor products on the market
produced by two different companies. So there are actually 4four comparable products, but only two different companies to compete against. KuhnRikon is a family-owned enterprise located in Switzerland which sells its products worldwide[2.4]. Schulte-Ufer is a tradition orientated company from Germany with nearly 125 years of experience in producing kitchen products[2.5].
Looking at the competitor products one aspect catches the immediate attention: Clearly the idea to sell a modern hay box is not new and probably the simplest solution for the project already exists. This would be a pot with a perfect fitting shell around it. It costs little effort to produce; heat convection of moving air does not need to be taken in account and by using a good insulation material the pot can be hold warm easily. A great disadvantage of this solution is that for every pot a corresponding shell is required. Therefore, in most cases the shell and the pot are sold together or are at least of the same brand. ComfortSavers actually wants the CookSaver to fit with the majority of pots on the market. Hence, the CookSaver probably will look different and there is no patent conflict expected.
Considering the price there is still room for improvement to make it more affordable. The first cost wish of ComfortSavers was below 80 Eros which is confirmed to be realistic, and can possibly even be lowered, as demonstrated in paragraph 2.5. Also the app provided by KuhnRikon costs extra money and only works for IPhones. The free alternative, a paper table, can become dirty or waste off in the course of time and is not a high tech solution. In short, there is room for improvement.

Product name	DUROMATIC® Power Steamer, Kuhn Rikon	DuroTherm, Kuhn Rikon	HOTPAN, Kuhn Rikon	Thermopot, Romana I, Schulte-Ufer
Product Picture				
Description	It is a pot for cooking under steam and pressure at the same time. An out coming pin indicates the necessary heat supply.	Food is heated on stove then the pot is set on an insulation base. A table indicates further cooking times.	It is a pot with a perfect fitting shell (ca.5 mm thickness). The lid of the pot is double-wall insulated and the bottom made of a sandwich construction	The product consists of a pot and a ca. 15 mm thick shell where it perfectly fits in. Food is heated up with the pot and then set into the shell. The insulation is complete with a second, insulating lid.
Material	Sandwich construction with chromium steel and ca. 10 mm air in between	The same sandwich construction as for the DUROMATIC® is used. Base is made of a polymer.	Pot: rustproof stainless steel Bowl: Melamin	Pot: Stainless steel. Bottom made with copper. Shell: Styrofoam.
Energy saving	Ca. 68%	Ca. 70%	Ca.60%	Yes, no numbers found.
Time savings	Ca. 1/3	Ca. 70%	Yes, no numbers found.	Yes, no numbers found.
Price	From 163€	From 179€	From 120€	From 35€
Capacity	4L-12L	1L -4.5L	1L-3L	2L-3.5L
Dimensions	22 cm diameter	18 cm or 22 cm diameter	18 or 22 cm diameter	16c m or 20 cm
Notes	Promotes with health, sustainability and simplicity App (0,99€) available to help using the device, only for IPhones available	No app available, just a paper table with cooking times included Still a lot of steps to cook a meal necessary. It is said to keep a meal 2 hours warm.	No app available, taper table with cooking times included; Won an award; Available in different colors 2 hours keeping warm. Special lid and special bottom	Recipes on internet available. Only fitting to Romana pots.

Table 2.10: Competitor products

2.4: For more information visit http://co-uk.kuhnrikon.com/co-uk/en/about_us/philosophy.html (English) of http://ch.kuhnrikon.com/ch/de/firma/philosophie.html ,German version
2.5: For more information visit http://www.schulte-ufer-kg.de/schulte-ufer/die-chronik/

The capacity in liters and diameter are used as an orientation for the dimensions of the CookSaver, together with the number of meals. No insight is provided how the values of "Energy Saving" and Time Saving" are calculated. Hence, for the energy and cost calculations it will be set as an aim to retrace them and to calculate a comparable value to compare the CookSaver with its competitors.
At last, something can be copied of the competitors. A sandwich construction shall be considered as well as a very thigh shell around the pot, as they have proved to be beneficial.

2.4.2 Trends of products

A lot of aspects play a role looking at trends, such as material, texture, colors and forms. Trends represent the global mood of the customers and the (worldwide) requirements. Now the actual trends on the market are pointed out.

Bruce Horovitz from "USA today" summed up the trends with the words "With few exceptions, most of 2013's new packaged goods products somehow make life easier, give a nod to cultural hot buttons and, in many cases, relate one way or another to a society that seems to spend as much time online as off."[2.6] Comparing the description with the device to be designed, there are already accordance's of the aspects easier life and life online. What this exactly means and how they are styled needs to be further defined.

At the beginning a style collage focusing on kitchen related products is made in order to screen different drifting's (Figure 2.6).
Based on the collage and an interview with the design office Bora Herke Palmisano about design developments on the market[2.7] , the four design directions can be determined.

1. Romantic/modern
2. Classical/Nostalgic
3. Extravagant style
4. Nature related design

Each of these categories has some characteristics in materials, colors and forms which lead to a trend-direction, table 2.11 illustrates the relation.

The modern/romantic look and the one of natural design have a lot of coincidences and could be combined. The classical style stands alone and the extravagant one is less applicable to kitchen devices. Table 2.11 is among others used as an orientation for ComfortSavers to point out where they see themselves on the market. They would like to fit the product within the natural or classical style. This choice has consequences for the material and color choice this decision has can be seen in table 2.11.
The thermodynamic properties of the numbered materials in table 2.11 should be checked to give consideration to their potential as insulators. In the case they are no usable as insulator; they can be used as design elements to package another, better insulating material. The materials characteristic for the natural or classical style are included into the wishes for the CookSaver. The reason why they are not requirements is that ComfortSavers does not want to limit the design process too much.

The trend is also towards eco-friendly products, produced in the region of the customers. Customers want transparency from companies to get a view into the origin and manufacturing of their products and the impact they have. This is also an expression of nostalgic-classical trends on

Figure 2.6: Collage of "trendy" products sorted by style

	Romantic/ Modern	Classical/ Nostalgic	Extravagant style	Natural design
Colors	Pastel colors	Black and white Red and metallic Metal colors	Combinations of neon colors	Pastel colors Aqua colors
Forms	Round Soft edges Nature looking	Sharpe lines Geometric Patterns	Geometric with generous surfaces	Soft edges Fluid lines Organic
Materials	Ceramic Knitting Glass Wood	Plastic Ceramic, pottery Glass Red with white and wood	Different kinds of plastic Synthetic textiles	Wood (Bamboo) Pottery Ceramics Glass
Product example				

Table 2.11: Trends on the market, based on Schöner Wohnen, November 2012, p. 14

2.6: http://www.usatoday.com/story/money/business/2012/12/30/2013-new-product-trends/1767425/ Checked: 13-07-2013
2.7. Source: Schöner Wohnen, November 2012, p. 14

the market. In a world which becomes continuously “smaller”, people go back to their roots and start to perceive more of their immediate surroundings. ComfortSavers needs to produce in Zeeland so this aspect needs no special consideration as it is yet pre-determined.

2.4.3 Dimensions of a modern kitchen

At this point a choice is made: The product shall be oriented at the kitchen-product related trends on the market and not on the kitchen itself. Hence, the standard dimensions of a kitchen and the standard dimensions of pots used in these kitchens are looked up. They can be found in Appendix P-B.

The most important dimensions to be considered are the height and depth of the workspace and the space between the upper and lower kitchen cupboards. These dimensions are 90/92 cm, 60 cm and 70-80cm respectively. The kitchen device should not extend a depth and with of 60 cm and a height of 72cm. These are the maximum values if it is assumed to place the CookSaver on the sideboard. In consideration with the results of the survey smaller values will be needed, if the user wants to store the kitchen device permanently on the cupboard. Consequently, the requirement will be to design the devices as small as possible but at least smaller then 60cm*60cm*72cm.

The standard dimensions for normal cooking pots is at a minimum 16/18 cm for 2l pots up to 20/22cm for a 3.5 pot. Assuming a 3.5 l pot is not necessary to cook a single ingredient meal for 4 persons (a family) the maximum diameter to fit into the CookSaver is 22cm.

2.4.5 Conclusion

There are a few products on the market which are competitors, but they are quite expensive and exclusive. It is always necessary to use it with a certain pot. A demand of ComfortSavers is that the future product is compatible with any ‘reasonably sized’ cooking pot, so there is still room in the market for the CookSaver. Investigating the existing products that proved to work information about their dimensions, structure and usage of material is obtained.
The trend analysis gives the design development process a direction. ComfortSavers does not yet have products to orientate towards so it was helpful to draw images of the future products considering colors and materials.
As a last step, dimensions are added to the requirements.

2.5 Determining design restrictions

Up to now some aspects are not yet discussed which are important because they will cause more design restrictions and requirements. This section comprises these aspects. The energy which can be saved by using the product needs to be calculated, a look at the legal framework must be done and a review of the restrictions due to the contact with food.

2.5.1 Calculation of energy and time savings

The final aim is to develop an energy saving device. A calculation is necessary to estimate the possible savings of time and money. ComfortSavers wants a payback time of 2 years for the customer. So the money savings a year are calculated which lead to the maximum cost price for the CookSaver. This has immediate influence on the choice of material and production process for the product.

For the calculations, the stoves are separated in two groups: Gas stoves and electric driven stoves. The separation is required as the costs for gas and electricity vary and so will the payback time for the customer. The time to heat up the food and to keep it hot until it is cooked is assumed to be nearly the same for both groups since the energy required is the same. Here is an average value of 1.7 kW is used, calculated from different kinds of stoves and sizes of boiling plates. An overview of all assumptions and the exact values can be found in Appendix CD-C.

The calculations are done for vegetables, meat and side dishes as they form the main part of the Dutch and German cooking culture due to the results of the survey. All calculations are done for single ingredient food and for a normal pot.
A further difference is made between “active cooking time” and “passive cooking time”. Active cooking time indicates that energy is used to cook, e.g. “the stove is on”, and passive is the opposite, e.g. “the stove is off”. The time which can be reduced is the active cooking time.

The time savings are calculated with an Excel table also to be found in Appendix CD-C.It is also possible to change values in the excel document to see how the cooking behavior influences the costs savings. As an average is assumed for cooking twice a week vegetables or meat and three times side dishes. To estimate the average values all costs are multiplied with 2 or 3.
On the next page an example of the calculation is given for potatoes, a food of the category vegetables and side dishes..

Example

1. Assumptions

- Constant values

  Mass water: m_1= 2kg
  Mass food: m_2=1kg
  T_1 = 5 °C =278K (food coming from fridge)
  T_2 = 100 °C =363 K
  T_3 = 15 °C =288K (starting temperature of water)
  Stove while heating: 1.7 kW
  Stove while keeping hot; 1kw
  Specific heat water: c_p=4.183kJ/kgK
  Costs gas: 0,0012 Euro/min
  Costs electricity: 0,0039 Euro/min

- Food specific values

  Specific heat potatoes: 3.43 KJ/kg°C
  Total cooking time: 15 minutes

2. Calculations

First, the energy to heat up the water to 100 °C is calculated:

$$Q1 = m1\ c(T2 - T1) = 2Kg * 4.183 * \frac{10^3 J}{kgK} * (363 - 288)K = 627.9kJ$$

Second, the energy to heat up the food and the total energy are calculated:

$$Q2 = m2\ c(T2 - T1) = 1kg * 3.43 * \frac{J}{kgK} * 95K = 325.85\ kJ$$

$$Total\ energy\ required: Q1 + Q2 = 953.75kJ$$

Afterwards, the time it takes the stove to deliver the energy is calculated:

953.75J /1.7 kJ/s ~561 s ~9.35 min

The time can be used to calculate the costs savings. The total cooking time of potatoes is assumed to be 30 minutes, so approximately 20 minutes are saved. So the costs to be saved are:

20 min 0,0012 Euro/min=0.024(Euro/one time) for gas*
20 min 0,0039 Euro/min =0,078 (Euro/one time) for electricity*

If it is assumed they are cooked twice a week it leads to the yearly costs:

*0.024 Euro/one time*2*52= 2.50 Euro/year for gas*
*0,078 (Euro/one time)*2*52=8,11 Euro/year for electricity*

Concluding, cooking twice a week potatoes costs 8.11 a year.

The assumptions for meat were different. Normally meat is not cooked, but roasted. Roasting the surface of meat takes very little time, but frying it until it can be eaten does. Hence, it is assumed to prepare meat with an oven which has consequences for the energy delivered and so the cots/ min and no water need to be heated up:

- Oven while baking/roasting: 4,00 kWh (gas and electricity)
- Costs gas: 0,00473 Euro/min
- Costs electricity: 0,016 Euro/min

Further the calculations are exactly the same as the ones for vegetables.

Results: The approcimated time savings are demonstrated in table 2.12.

	Times cooked a week	**"New" achtive cooking time (min)**	**Time saved (min)**	**"Normal" or "total" cooking time (min)**
Vegetables	2	9	15	24
Meat	2	3	31	34
Side dishes	2	9	15	24
Final average	-	7	20	27

Table 2.12: Supposed time savings with the CookSaver

In words it means the user is in average 27 minutes a day buys with cooking and there can be 20 minutes a day be saved. This assumptions lead to a theoretical reduction of ca. 75% of time when the food is placed in the CookSaver. In fact, this time calculation is not very meaningful for the customer, because it is not necessary to pay all the time attention to the food on the stove. However, looking at the market analysis, it makes the numbers for time savings of the competitors comprehensible.

Now the time saved is known, it can be converted into approximated costs saved, as in the example is done. It leads to the following values (rounded, table 2. 13):

Kind of food/ money saved	**Times cooked a week**	**Money saved with gas (Euro/year)**	**Money saved with electricity**
Vegetables	2	2	7
Meat	2	18	60
Side dishes	2	2	6
Final average	-	7	24

Table 2.13: Money savings in correspondence to cooked food

With gas there could be 7 Eros a year saved and with electricity 24 Euros. In average it would be 16 Euros a year and the cost prices of the CookSaver is at a maximum 32 Euros.

Limitations and conclusion of the calculation

A lot of values are assumptions, for example, the electric energy price differs slightly between e.g. the Netherlands and Germany, and the energy content of gas per m^3 depends on the gas used. Once more, mean values are taken or the most common one. In general, the Netherlands and Germany have one of the highest energy prices in Europe and prices will raise more.

On the one hand the required energy to heat up food is an approximation as the exact value depends on many constants. For example, the dimension of the pot, the material of the pot, how much food and water are cooked, air pressure and surrounding temperature. On the other hand, the energy also depends on the behavior of the customer: If a lid is used, if the heat is lowered when the water cooks, if the stove is used to heat food up or, for example, the microwave. Furthermore it is said in the survey that families with children use the stove more often than people without children. As already mentioned, the data are not very reliable at this point, but if assumed the stove will be used three times a week, the savings already will be 22 Euro. The values should be treated carefully and always have in mind/thought they are based on average values and estimations

Over all it can be stated, the resulting value of 17 Euro savings a year is a very row assumption. It is regarded to be very low value and based on the value the final costs price of the CookSaver needs to be very low.
In reality, the value should be higher so that the final conclusion, established together with ComfortSavers, is to make the device as low cost as possible and the money saved at least 25 Euro a year. It is considered as very probable that the money saved is of a comparable order.

Besides a recommendation is that the future app should be able to calculate the energy savings based on information given by the user. In this case the user could get an impression of how to manage energy consumption by changing the cooking behavior.

2.5.2 Legal framework

A short look was done to the legal framework. There are a few patents to be considered coming from Japan although their products are not yet available on the European market [2.7]. One for example, is over cooking bags which look exactly like the traditional one shown at the beginning on page 2, figure 2.2. Further the product may not look like the competitor products which were shown on page 7, section 2.4.1.

2.5.3 Restrictions due to working with food

There are regulations and limits if you develop a product a product for use in the kitchen. Besides the common ones, such as non-toxic and easy to clean, here the ones related to isolation play an important role. Besides an internet and book based research, an interview was done with a 3rd year student “Food technology” of the University of Wageningen of which a summary is presented in Appendix P-D.
As safety temperature mostly 60°C is taken, because bacteria’s grow well below this temperature. The temperature differs respectively to the kind of food cooked, but basically is a good limit. At this point the old cooking books for hay boxes are revisited to find out how long the single-ingredient meals need to be cooked. It depends on the kind of food, but can be estimated with 30 minutes.
If the cooking process is longer but at a lower temperature the vitamins in the food remain nearly the same as the one of a normal cooking process. High temperatures destroy vitamins and a long term “higher” temperature has the same effect.
Concluding, the food will not be healthier using the insulating product, but it will not be worse, neither.

2.5.4. Conclusion

With the last section missing requirements could be added to the program of requirements. The maximum cost price for the CookSaver is set as 50 Euros. It became clear there are few patent restrictions and it can be set that the CookSaver has to keep the food at least 30 minutes at a temperature higher than 60 °C. In the following section the requirements are yet used as constraints for materials.

2. 6 Material analysis

At the beginning ComfortSavers had the wish to get an early impression of the materials which can be used to insulate, but also to not limit the design process. As middle ground a list of 12 materials including insulating materials of different sources is set up. All are satisfying the basis requirements, called constraints. In collaboration with ComfortSavers some materials are chosen to be regarded in the design development process.
The intermediate results as well as the explanation can be found in Appendix CD-E. A short summary about how the research

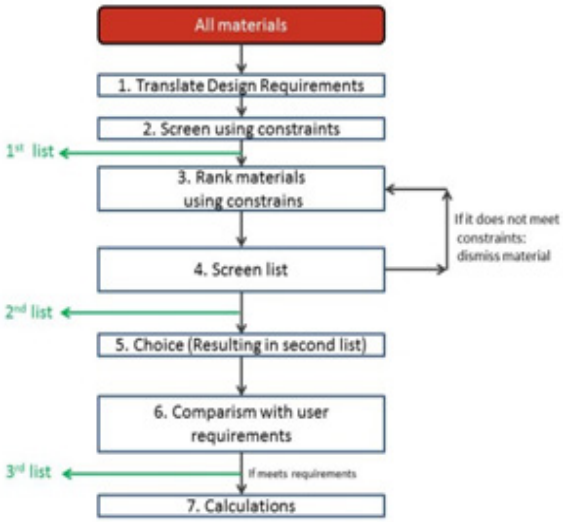


Figure 2.7: Workflow to establish a base of materials

2.7 Found on different forums : http://www.utopia.de/gruppen/selbst-machen-177/diskussion/kochkiste-selber-machen-93806 (28.5.2013), and http://www.chefkoch.de/forum/2,52,610976/Kochen-in-der-Kochkiste.html (28.5.2013)

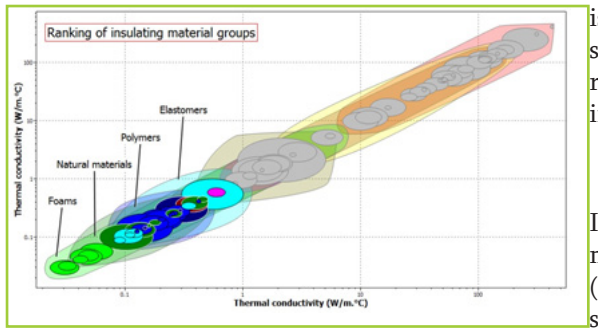


Figure 2.8. Example of screening with CES

is done and further the results are presented in the next section. If talking about requirements the program of requirement in section 2.7 is meant.

2.6.1. Material reearch

In order to determine the best matching materials, an iterative workflow is set up . (Figure 2.7) [2.9]. The workflow starts with step 1: Translating the known requirements of the market and trend analysis into functions, constraints and variables:

Material	k (W/mK)	Material	k (W/mK)
1. "Vacuum"	0	7. Wood fiber plates	0.045
2. Vacuum insulated panels	0.004	8. Perlite	0.058-0.138
3. Aerogel (solid)/Bluedec®[2.11]	0.0135	9. Paper and cardboard	0.06-0.17
4. Air (motionless)	0.0257	10. Softwood (acrossgain)	0.08-0.14
5. Cork	0.035-0.048	11. Bamboo	0.1-0.18
6. Sheep wool and cotton	0.035-0.04	12. Polylatide (PLA)[2.12]	0.12-0.13

Table 2.14: List of well-insulating materials which fit to all requirements obtained of the analysis

1. Translate Design Requirements

- Function: Insulating heat
- Constraints:
  - Thermal conductivity: As low as possible
  - Thermal diffusivity: as low as possible
  - Thermal shock resistance up to 120 °C
  - Thermal expansionThermal radiation
  - Max. service temperature is at least 120°C
  - Recyclable
  - Eco-friendly production process
  - Dimensions: 60cm*60cm*72cm
  - Resist fluids
- Object:
  - Minimize thermal conductivity
  - Minimize the impact on the environment
- Free variables:
  - Choice of material

Step 2 is researching different sources for well insulating material. It is an internet, book[2.9] and CES[2.10] based research done including materials of construction of scientific purposes.
Out of the separate researches one list is assembled ranking all insulating materials to their thermal conductivity. Step 4 is to screen them regarding the constraints figure 2.8 (example of screening with CES).
If a material does not fit them, it is dismissed of the list. This procedure results in a second list with materials regarding the constraints of the market and trend analysis. Finally the materials are screened again considering the requirements of the user coming from the target group analysis. This results in the 3rd, final list of 12 materials. Step 7 already refers to the implementation of the materials into concepts.

2.6.2 Resulting list of materials

The thermal conductivity at 20 °C is chosen. It is an independent value and gives a good first impression of a material, further it will be the value for the begin situation of cooking. The mentioned 3rd list is given in table 2.14.

2.6.3. Conclusion

Not surprisingly vacuum is the best insulator as it does not transmit heat at all behalf by radiation. Vacuum panels are used in construction and are very fragile and therefore less suitable. A less sensitive alternative is Aerogel/Bluedec® or just non-moving air. Aerogel is a very expensive material used by the NASA and Bluedec® is the cheaper alternative.
Furthermore it is remarkable that there a lot of good, eco-friendly insulators which fit well to the image the company want to creates of itself and to the trends. There are for example natural looking wood, cardboard, cork or bamboo. Materials used in construction, as foam, Bluedec® or stone, also provide a lot off good isolation materials. Less suitable are materials coming from trends such as glass, ceramic and potter. They can only be used for details added to the design, not as main insulator and therefore are not included into the list.
In any case, a good list of materials is obtained to start with the design and, in collaboration with ComfortSavers, the materials Aerogel and Bluedec® shall be assimilated into at least one concept. They are considered to be attractive for marketing purposes as they are very new and "high-tech". It is a good addition for the appearance of company who wants to have a trend following and setting image.

2.9 Based on Ashby, M., Shercliff H., Cebon, D.(2010) , Materials, Figure 3.6, p.36, BH).
2.10: CES Educational pack 2012: Educational data base for materials

2.7 Program of requirements

Based on the research a program of requirements and wishes is set up which the CookSaver needs to fulfill. A few requirements are at this point added by ComfortSavers.

Requirements

Geometry

1. Not extend 40cmx40cmx70 cm
2. Needs to be suitable for a pot with a diameter between 16 and 24 cm
3. The CookSaver needs to stand stable on any kind of surface

Aesthetics

4. The CookSaver should fall within the classical or natural design
5. Contrasting materials should be used
6. The appearance should be healthy
7. The appearance should be self-explaining
8. The CookSaver should look different than a simple scarf/cloth
9. The appearance should be “straight”

Cost

10. The maximum payback time for the customer should be 2 years (or the maximum price of the CookSaver should not be more than 50 Eros)

Performance

11. Single ingredient meals (one pot) should be prepared safely
12. The device should be reliable
13. The device should be able to prepare food without contaminating the food
14. The device should reduce the active cooking time to a max.of 15 minutes
15. The device should save 60% energy
16. The final temperature of the meal should be at least 60 °C after 30 minutes

Physical

17. During the cooking process the outside surface temperature needs to stay below 45 degrees
18. The CookSaver may not to be opened by children
19. The kitchen device should not extend a weight of 2.5 kg without food

User

20. The CookSaver should be easily portable within short distances
21. The CookSaver should be cleanable within 5 minutes

Environmental

22. The CookSaver should be resistant against fluids
23. The CookSaver should be resistant to dirt
24. The CookSaver should be resistant to cleaning supplies

Regulatory and licensing

25. It should look different than a simple scarf/cloth

Material

26. The used materials should be recyclable or biodegradable or stay in “techno sphere”/re-usable
27. The used materials should be non-toxic
28. Resistant against cleaning supplies
29. The used materials should be resistant against food and liquids
30. The used materials should have a thermal shock resistance higher than 120°C
31. The used materials should have a max. service temp. higher than 120°C
32. The production of the materials should be ecofriendly

WISHES

Geometry

33. More than one pot can be placed in the kitchen device

Aesthetics

34. It does not look like a simple pan

COSTS

35. Does not cost more than 75 Euro

Performance

36. A second version for a lower price is available without a related application
37. The device should save 70% energy
38. The kitchen device can also be used to cool something.
39. The kitchen device should be usable for pots between 1-8l
40. The device can be sold together with a presser cooker for one-pot meals

Physical

41. The kitchen device should not extend a weight of 1.5 kg without food

User

42. The kitchen device can partly be placed in the dish washer

Material

43. Material is anti-bacterial
44. Ceramic, knitting, glass wood or pottery should be one material of the CookSaver

2.11 Bluedec consits of aerogel fibers enclosing air, it is insulates as good as solid aerogel but less expensive
2.12 Polylatide (PLA) is a biodegradable plastic

3. Concept development

At the beginning of the concept development, a morphologic scheme was done to picture sub-problems and sub-solutions. Some of them were chosen as a start-up for concepts and ideas. The morphologic scheme and some impressions of the development process can be found in Appendix P-F.
Furthermore it was necessary to measure once again some pots to determine the dimensions of the concepts. Especially the handles and the height including the lid were required to estimate the dimension of the CookSaver. The data can also be found in Appendix P-F. For the estimation of the thickness of the sandwich construction the competitor analysis is used.

3.1. Concept 1-Hanging

In Figure 3.1 a 3D picture demonstrates the shape of the concept and a 2D one simulates the structuring. Basically the normal cooking pot is hanging into a \ second, insulating pot including a second lid.
Intended is a sandwich construction of stainless steel or, suggested as alternative by ComfortSavers ABS, and a “filling” of air or vacuum for both, the pot and the lid. The material for the handles of the pot and the one on the lid will be wood as it is also a good
insulator. In figure 3.2 the working principle of the handles is demonstrated. Firstly, the wooden handles are clamped on the wall of the pot. Secondly, the pot with the food is hanged into the handles. Within the handles a drawer is placed. It is needed because the outer walls are one size but a flexible support for handles of pots of every sizeis required.
Therefore a small rubber block is applicated to the inner surface of the moevable drawer which fits into the recess of nearly all pot handles.
Finally the second lid is placed above the pot lid. To ensure the insolating effect of the pot, the handles have a form which
corresponds to the one of the lid and no space remains for the heat to escape. If the food is ready, only the lid needs to be removed and pot with food can easily be lifted up and placed on the dining table if wanted. The advantage is the wooded, second handles protect as the handles of the cooking pot are probably hot, too. The second handle prevents burning hands and simplifies the lifting process which was otherwise very complicated.
The probable dimensions of the product are demonstrated in Appendix F.
Material, necessary for a prototype, would be wood and plastic plates to be vacu-

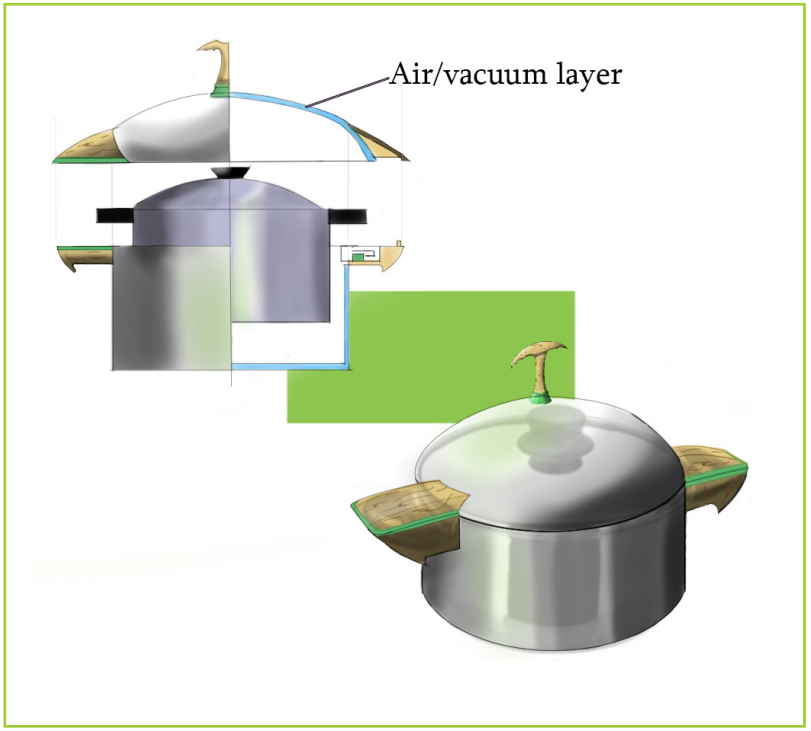


Figure 3.1: 3D view of the concept

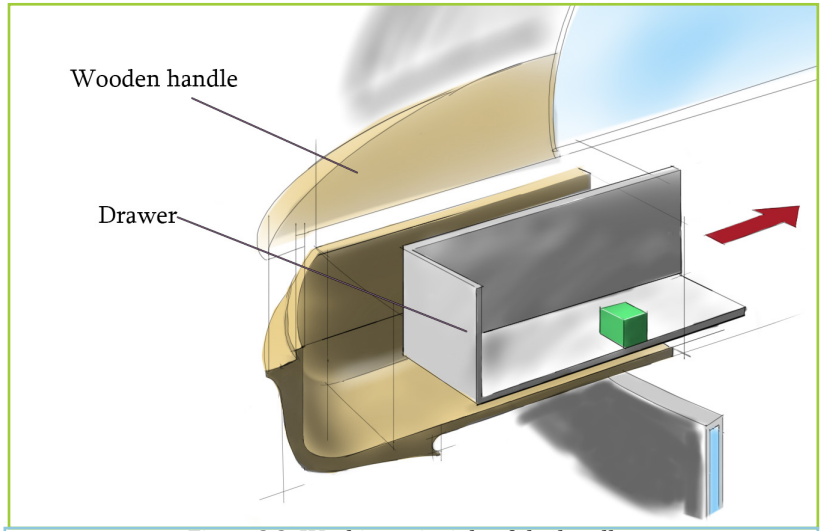


Figure 3.2: Working principle of the handles

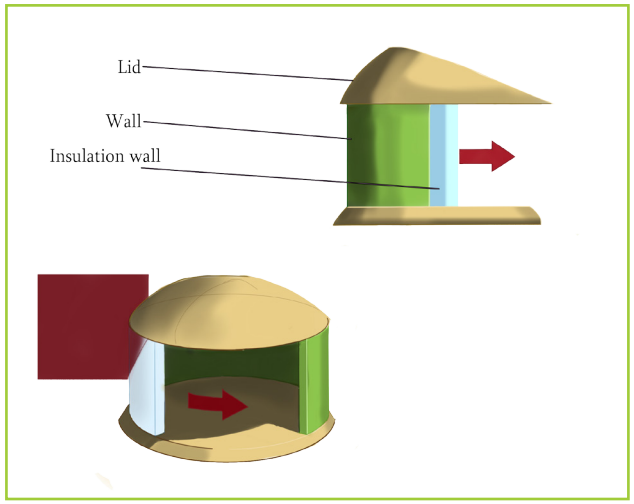


Figure 3.3: Modification 1 of concept 2

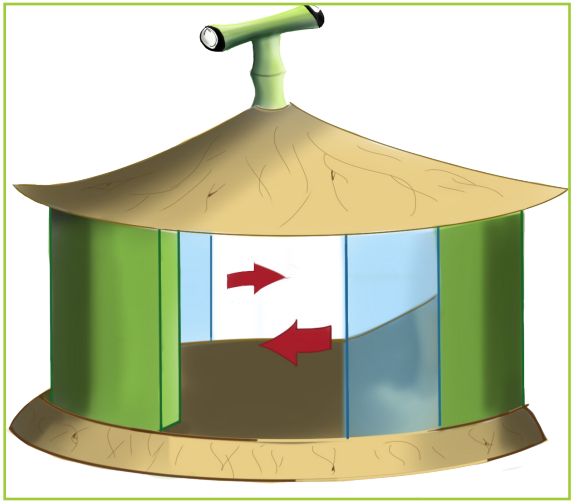


Figure 3.4: Modification 2 of concept 2

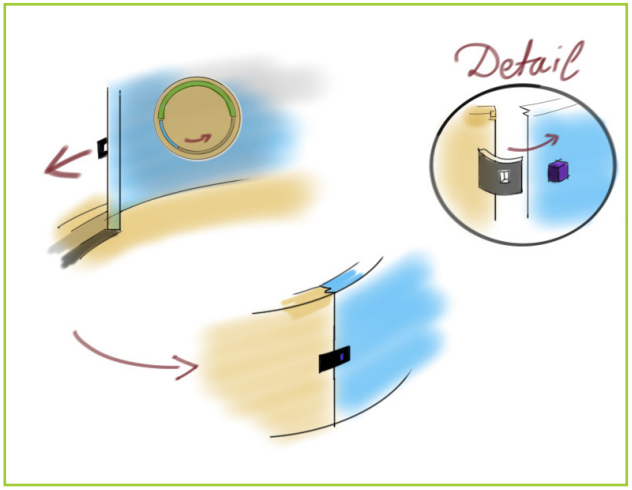


Figure 3.5: Groove and clamp mechanism

um formed in sufficient thickness. Dependent on the choice, a vaccum pomp would be necessary (if assumed the prototype to be of high quality).

3.2 Concept 2-Chinese garden

There are two modifications of concept 2 (Figure 3.3 and 3.4) which differ slightly but are based on the same principle. The components of this concept are a lid, one or two “walls” and an insolation wall to pull out the CookSaver.The common idea is to enclose the pot for insulation by extracting a closing wall to complete a circle form. To ensure the form is really closed and no gap remains where heat can escape, two details are illustrated. First the transparent, aerogel door follows a narrow, but precise fitting groove.
In figure 3.5 the principle is demonstrated at the bottom of the concept. At the upper side of the door also such a groove is inserted to the lid.
Second, the door and the opposite side need to be closed precisely. Therefore two little extras are added. The end-side of the door and the contact side of the backside work as two pieces of a puzzle and a clamp fixes the position (Figure 3.5).
Modification 1 has got a half-circle backside out of which a half circle front side can be pulled to enclose the form. An advantage, making this concept unique, is that the pot with food can be set into the device from the front. The main disadvantage of this concept is that the height between insulated ceiling and upper side of the lid needs to correspond to the average height of pots which leads to unnecessary space in between.

Materials for this concept would be wood or a coating, aerogel, airglass[1] or Bluedec®[2] and a biologic polymer. If this concept is chosen, probably the price will be higher than set in the program of requirements. The lid and the insulation floor should be insulted with a layer of bluedec.

Modification 2 is based on the same materials but has two quarter walls which include each two closing walls (Figure 3.6). The closing walls need to clamp at the opposite. So there is a double insulation wall created consisting of two layers of aerogel, airglass or bluedec including a layer of air.

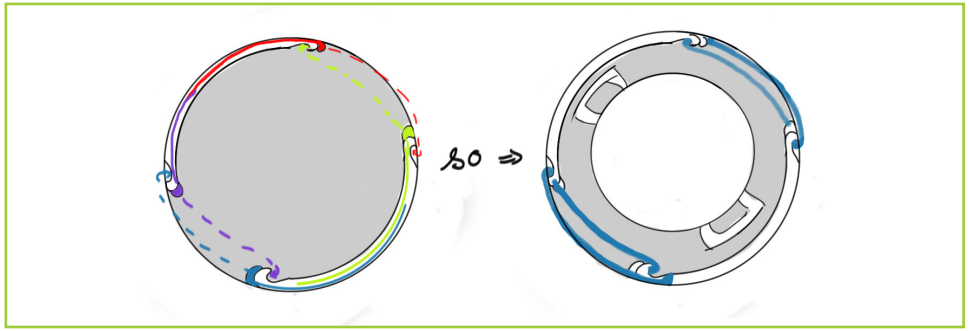


Figure 3.6: Double wall system

1: “Airglass”is a very tranpsarent aerogel, http://www.airglass.se/ , (17-6-2013), Realability Confirmed by Joost Duvingeau, Aerotech Twente
2: “Bluedec”is an insulating material coming from construction which consist of aerogel fibers with enclosed air, http://www.bluedec.nl/, Wassing, Toine, (17-6-2013)

An advantage of this modification is a higher stability compared with modification 1, and a more gadget like appearance. Disadvantages are a higher effort in use and the pot with food needs to be set in from above. Also, the price of the concept might be higher. The dimensions can also be found in Appendix F.

3.3 Concept 3-Boat

In figure 3.7 a picture of the 3rd concept can be seen. The basis surface is boat-shaped and formed around a pot.
In Figure 3.8 the working principle is demonstrated. The concept consists of three parts: One basis which is comparable to the bow of a ship and two lid parts which need to be opened to place a pot inside. The handles of the pot need to be placed at the front- and backside of the concept. The oblique surface makes it possible to lift them up after the food is prepared.

On the side the surface has a notch to make the product portable.
Alternatively to the boat shape a circle shape would be possible. An idea for construction is demonstrated in figure 3.9. The emphasis was a healthy appearance, good insulation and giving a high tech appearance. Part 1 and 2 are two boat-shaped bowls made of wood of ABS (suggested by ComfortSavers. Part 2 is significantly

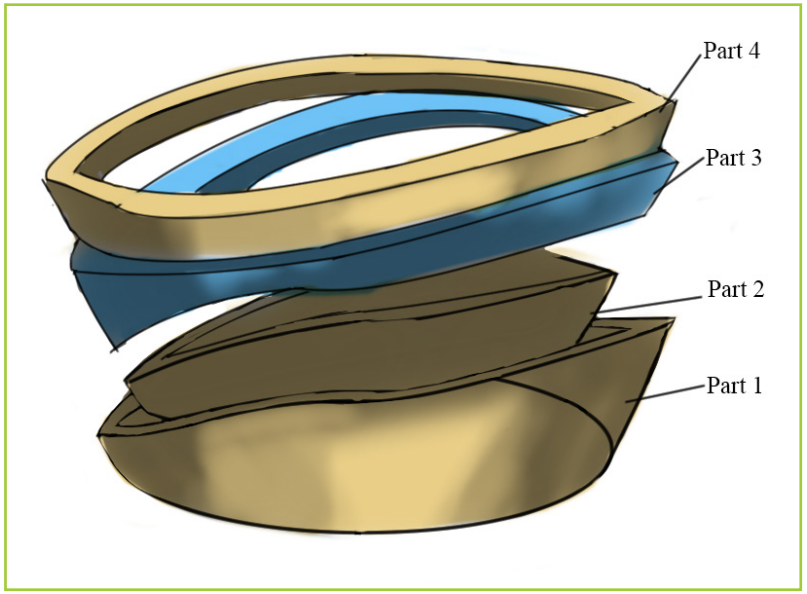


Figure 3.9:Construction of the bottom

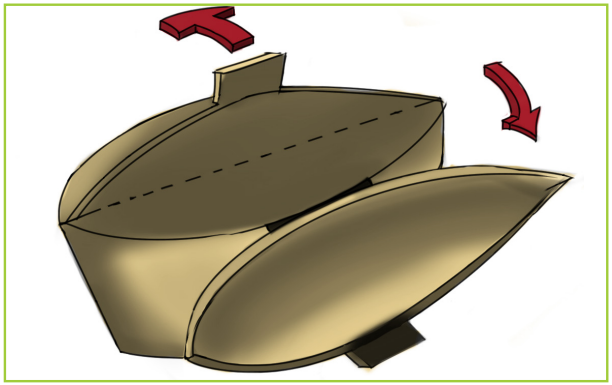


Figure 3.8: Working principle

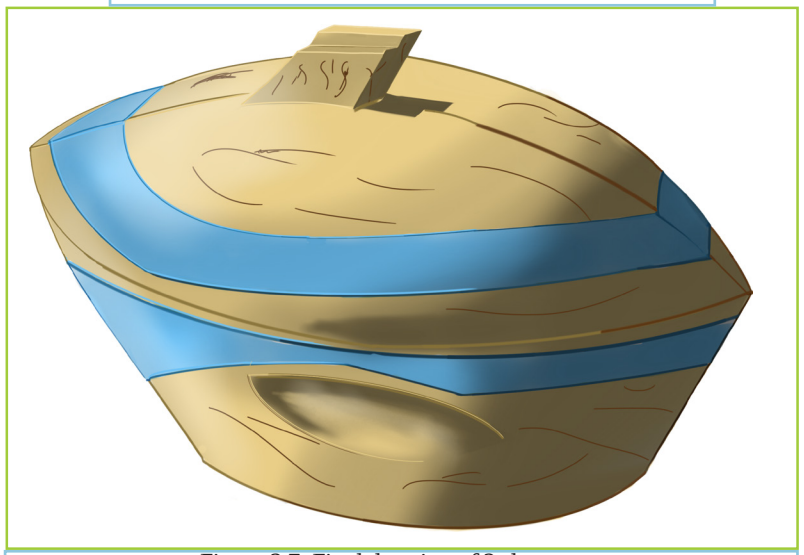


Figure 3.7: Final drawing of 3rd concept

smaller than part 1. They are enclosed by part 3 which is made of transparent Aerogel. Between part 1 and 2 an air layer is generated for extra insulation. Above the Aerogel part a wooden or ABS ring is fitted (part 4) which encloses the structure, adds stability and provide a stable place to apply a hinge.
The two parts of the lid are similar constructed. A high advantage of this construction is its flexibility. The wooden parts could also be made of aerogel or a grid filled with aerogel. Actually aerogel is a very expensive material which costs between 3500 -5000 Euro/m^3 [3.1], so it could be replaced by a cheaper, insulating material if this becomes affordable in the future. In any way, for promotion purposes small amounts of aerogel already could be implicated. Nevertheless, two different materials need to be used with different colors. Due to the results of the survey it makes a product more interesting and attractive.

3.1: Referring to Joost Duvingeau, Aerotech Development, Twente, MESA+ Institute for Nanotechnology

3.4. Evaluating concepts

The choice for one concept is based on three aspects:
- Comparison with the requirements
- Discussion of feasibility
- Discussion of design aspects

The feasibility is discussed with the attendants of the University, Wessel Wits, and of the Company ComfortSaver, Edward Mouw, as they have experience and knowledge about producing products.
The design aspects were discussed with Edward Mouw as he needs to consider the concept as suitabl.

3.4.1 Discussion of feasability

First of all it can be stated that all three concepts are realistic, satisfy the requirements and could be realized as prototype. As not yet worked out entirely in every aspect possible failures and problems are discussed here. The probability to solve them is discussed to give ComfortSavers an impression of the further development and to have a basis to go on with the chosen concept.

CONCEPT 1-HANGING

The stability of the drawer could form a problem, therefore an exact model needs to be made and the maximum moment needs to be calculated. A higher stability could be obtained if the drawer and the handle go over in each other directly without a connecting joint. It is very probable that it will work out if the expansion of the materials is taken in account.
Furthermore, it is very difficult to create a permanent vacuum insulation layer, air instead will be enough. Another possibility could be to add Aerogel, but the implementation of this material raises the costs. An advantage of this concept is that the hot pot barely touches the insulation shell but is surrounded by air which enlarges the performance of insulation. Every “cm” air provides extra insulation and less contact means fewer places where heat is lost and increases the insulating effect of the concept.
The connections still need to be regarded in detail. Especially one of the handles because this needs to be really stable to ensure portability.

CONCEPT 2-CHINESE GARDEN

Crucial for this concept is not only the discussion of the concept itself, but also the comparison of the two modifications. Modification 1 seems to be easier in use, and needs less material but also looks less fancy. The extra insulation layer of modification 2, created by two enclosing layers of aerogel, is not necessary because of the high amount of air around the hot pot. It can just be a source of insulation failures and is considered to be not suitable enough and is dismissed
Of concept 2-1 the bottom forms the main cause of failure. Due to the big surface of contacts, a lot of heat can escape. A solution could be to add ribs to the bottom and thereby reduce the surface of contact between the CookSaver and the hot pan. At the same time more space for air is created which enlarges the insulation effect. The most important disadvantage of this concept is that it is not portable.

CONCEPT 3-BOAT

Basically this concept would work but needs some extra support between the two layers of the ship’s bow. If the concept is made of wood it would be too expensive, so a different material should be used. Of course, the natural effect would also be lost, if using another material than wood. Therefore a coating or two different materials for the inner and outer shell can be considered.
Further contact between the hot pot and the insulating CookSaver should be reduced to a minimum. If the concept is chosen, the ability to lift up the hot pot should be controlled. Alternatively, the concept could be divided vertically and opened like the doors of a cupboard and, if this is not sufficient, it could still be divided horizontally to flap the upper side away. By the way it would reduce the cost because half of all molds would be necessary due to the new created symmetry.
The overall conclusion is that Concept 1, concept 2-1 and concept 3 are realistic to produce and to develop further in detail. There is still room for improvement at all three concepts.

In order to say something about cost calculations are done to be found in Appendix CD-G . Second, to see if the payback time of 2 years is realistic, a spreadsheet was made to estimate the production costs of the concepts. They are calculated for Concept 1, Concept 2-1 and concept-3 as they have the highest scores. The calculation is done to establish a maximum price. The results are approximately:

Concept 1:	34
Concept 2:	30
Concept 3:	32

There are some differences, but none of the concepts can be dismissed due to impossibility to produce or too high producing costs. Further it is with all three of them realistic to reach the aim of a 2 year payback time. It is of special interest that the intelligent use of aerogel in concept 3 does not directly mean higher costs.

3.4.2 Comparison with the requirements

Based on the analysis phase some requirements and preferences of the target group are stated which will be now revisited to look which concept brings the aspects of functionality, healthy appearance and gadget-like experience best together.
Concept 1 has a very high functionality, is assumed to be very save, but does not have a very fancy appearance. Looking at the design, no high-tech applications as an app are assumed to be related to the product. It looks too much as a normal pot.
Concept 2 and 3 are comparable. Both look modern and the addition of aerogel gives the impression of a modern, high tech material. If they actually look healthy is relative, but they give already a gadget- like feeling. Furthermore their functionality is comparable but concept 3 has an advantage as it is portable and easier to storage because the construction is more stable.
Summed up, all concepts have aspects according to the requirements of the target group, but after a concept is chosen the detailed design should focus on the requirements and preferences of the user and enhances his experience. Especially the relation with the app and design characteristics of a healthy appearance should become more visible in the concept.

3.4.3 Discussion of design aspects

Finally the requirements and wishes are compared with the concepts by adding weight factors to each requirement and give a score in how far a concept satisfies the requirement.The score and the weighting factors are multiplied for each requirement and concept and finally summed up to the final scores. As most important are performance and safety requirements considered followed by the appearance
related ones. The discussion of feasibility and design is used to estimate the scores. At a later point requirements will be added for the app, but instead for all three concepts it will only be worked out for one.
To calculate the final scores of the requirements, an excel document is used which can be found on in Appendix CD-G.

The summarized results are:

	Concept 1-Hanging	**Concept 2-Chinese garden 1**	**Concept 2-Chinese garden 2**	**Concept 3-Boat**
Score	343	347	331	365
Satisfied wishes	6	5	5	6

Table 3.1: Scores of the requirements

It can be seen that concept 3 reaches the highest score with 365 points. It is followed by concept 2-1 with a relative score of 347 points.
Actually they are all very close, buthe lowest scores have concept-1 and concept 2-1. Concept-1 scores are very low at the design related requirements and concept 2 at the functionality related ones. Based on the scoring concept 3 should be chosen.

3.5 Choosing a concept

Evaluating all numbered requirements and discuss them with Edward Mouw and Jeroen Verschelling from ComfortSavers, concept 3 is chosen to be worked out.
The main change at this point is, that the in collaboration with ComfortSaver, it is decided to make the final prototype also working for a pressure cooker. Up to now it was a wish for the CookSaver to be designed in such a way, that it is also usable with a pressure cooker.
Furthermore the placing of the joint should be reconsidered to increase the ease of use and the functionality. Thinking of the most important purchasing factor of the future customers, which is “functionality”, it is very important to enhance it as far as possible. The healthy appereance will also be reconsidered as it is not considered to be satisfactory.
At last an alternative material for solid Aerogel neds to be found and instead of wood the side walls are chosen to be made of ABS.

4. Detailed elaboration

A few aspects of the concept need to be adjusted and reconsidered for the final design.

ComfortSavers has, after the concept development, expressed the wish to sell the CookSaver with a pressure cooker inside. Until now the concept was only developed for all common pots, but they would like to see in how far it is possible to adjust it to be usable in combination with a pressure cooker (figure 4.2).

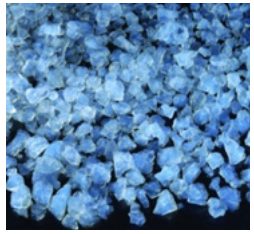


Table 4.1: Lumira® Aerogel particles

Besides, the healthy appearance needs to be underlined by adding details. In first instance the concept was meant to be made of wood, but as it is too expensive. ABS will used instead as suggested by ComfortSavers. They note that they accept the use of ABS under the condition it can be easily separated of the other materials for recycling purposes.
Second, instead to use a solid layer aerogel, which is very fragile, it seems better to make a transparent ring of Polycarbonat (PC) and fill it with Lumira® Aerogel particles produced by Cabot (figure 4.1). It is signed to be “Cradle to Cradle” and non-toxic, but causes skin

and eye irritations with no permanent damages. It asks immediatly for special attent- while integrating it into the product. It needs to be inaccessible for the customerThe ring may not be opened easily or breakable.
Due to this change of material the texture, the feeling but also the charism changed and need a revision Also the construction and how to enlarge the insulating effect needs to be worked out in detail.
A 3D model is necessary to calculate more precisely cost, weight and insulation performance.

4.1 Adjustment to a pressure cooker

In figure 4.2 there are four typical pressure cookers visible. The form actually differs from a common cooking pot more than a little. Looking at the pictures two main differences could be pointed out. The first is the height which is significantly higher than normal cooking pots, and secondly one handle is longer than the other. Both aspects have a lot of influence on the appearance and usage of the product. Sometimes even electronic parts are attached to the pressure cooker with unknown functions.

Figure 4.2: Different kinds of pressure cookers

Now, imagine one product, fitting for all kind of pots. If placing a little pot of small diameter a lot of spaced would be wasted (with air) which decreases the insulating effect as it increases convection. Motionless air cannot be supposed any longer. Further the product would be unnecessary big and could not be easily stored. Also the production cost production will rise. Concluding, it is not desirable to have one-for all devices.

If a solution was demanded anyway, the CookSaver could be sold with two lids, one enclosing one and a second one with a gap for the longer handle, but this reduces the insulating effect.
To be able to do tests with and without a pressure cooker and compare the results with a prototype the dimensions will be oriented at a small pressure cooker and a big pot.Hence, a fitting pressure cooker is bought (figure 4.3)

Figure 4.3: Small pressure cooker, bought for the prorotype

4.2 Adding details for a healthier appearance

Before adding details a short look is done which characteristics make products healthy, looking eco-friendly and which possibilities there are considering the chosen materials ABS and PC.

Figure 4.4: Eco-friendly and healthy products in a collage

Healthy:
- Transparency
- Usage of natural materials
- Mainly green or blue colors
- Representation of product with healthy food

Eco-friendly:
- Natural materials
- Natural structures/textures
- Green and brown as colors

Both:
- Labeled to be ecofriendly/ recyclable/C2C

Now it is looked how these aspects can be integrated in one concept: PC is transparent which makes the Lumira®Aerogel visible. Meanwhile the Lumira® Aerogel is signed to be Cradle to Cradle and ABS is recyclable, therefore adding labels is a good detail to inform the user about these advantages of the product. In any case it is not enough, because the first impression is very important and labels do not catch immediate attention.
So a short review of the possibilities of ABS is done:

Characteristics:

- Freedom of colors
- "Difficult" corners possible
- Thin structures possible
- Mainly smooth surfaces
- Surface structures possible
- Recesses possible

Figure 4.5: Collage of ABS made products

Combining these aspects the following details are added to the concept:

a) Two stickers or mould-included symbols indicating the C2C Aerogel and recyclability of the product (Figure 4.6). However the Cradle to Cradle symbol is a suggestion. Before placing it on the final product, on the one hand Cabot should be consulted. On the other hand the Cradle to Cradle symbol requires certification[4.1].

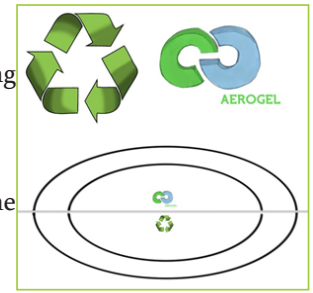


Figure 4.6: Recycle and cradle to cradle symbol

As suggestion, if they can be applied, to place them at the bottom of the CookSaver. So it does not disturb the straight appearance of the product.

b) Second, the material was chosen to be wood, but seemed to be too expensive. Therefore it was switched to ABS which opens new possibilities but deletes the nature-like appearance.

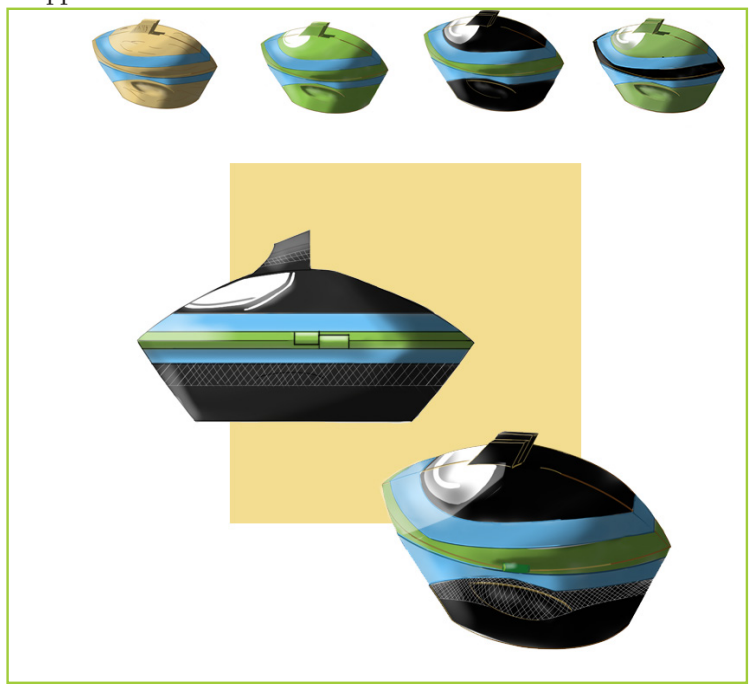


Figure 4.7: Colour variation and final concept

In the foreground are now the textured the coloring oder to recover to recover the healthy appearance. The colors and green and blue are chosen in relation to the cradle to cradle colors and healthy-associations. The green material is considered to be dimmed, the blue one transparent and the black one shining. At the bottom and around the handles a texture is added. On the one hand to enhance the user experience and improve the adhesion, on the other hand to make the design more interesting regarding to the survey. Black as basis color is chosen, because it provides a neutral background and matches with most colors of kitchens.

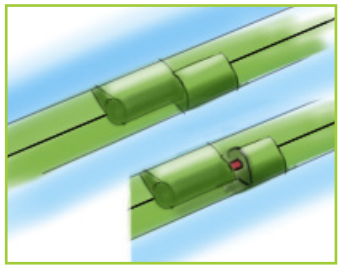


Figure 4.8: Integrated joint

Color has also influence on the heat absorption or reflecting properties of an object. So it is a good thing to make the CookSaver black from the outside, to absorb environmental heat, and to make it white or reflecting from the inside. The prototype can show if it makes a notable difference.

The ratio of the layers is represented in figure 4.7. The joint shall be placed as low as possible, at least below the handles to make at as easy as possible to lift the filled cook pot up again. Further shall the joint be integrated into the mould and not made off another part (figure 4.8)

4.3 Reconsidering structure

At the beginning a basic understanding of the principle of insulation and how insulation works was assumed. At this point it is looked at some more detailed examples in order to get inspiration how to enhance the insulation effect of the product. The bottom is considered to be the main cause of heat loss and therefore is in need of a redesign. At the same time it is supposed that the construction is not yet stable enough to carry a filled pot of food.

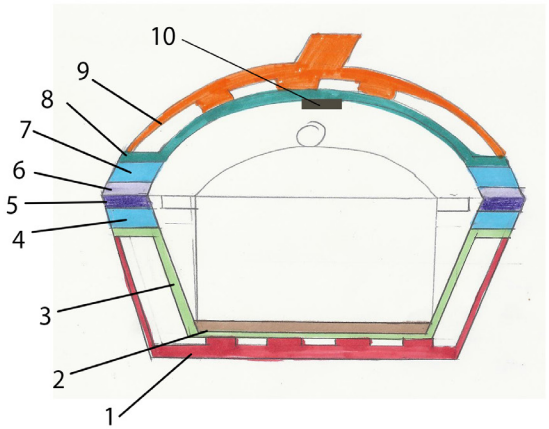
Figure 4.9: Stiffners in a boat

4.3.1 Structure

A solution is found to both problems. The shape of the CookSaver reminds of a boat and so the structure to stabilize the construction can be copied of a boat. Just like in a boat on the inner walls of the bottom shell there are stiffeners added (figure 4.9). The new structure, including the names of the parts, is demonstrated with a section view in picture 4.10.

The stiffeners have to be at least applied between the bottom shell (4.10, 1) and the inner shell (4.10, 2), and between the inside (4.10. 8) and outside lid (4.10,9). Dependent of cost and effort they can also be added to the side walls. Besides, the stiffeners form small chambers. Possibly it improves the insulation effect because they reduce the circulation of air (if it happens).

4.1 For more information visit: http://www.cradletocradle.nl/home/322_certificering.htm (27/7/2013, checked)



1 Bottom shell
2 Extra cork layer
3 Inside shell
4 First aerogel layer
5 Enclosing ring 1
6 Enclosing ring 2
7 Second aerogel layer
8 Inside lid
9 Outside lid
10 Small magnet

Figure 4.10: Section view including the stiffners and names of the improved structure

4.3.2 Insulation

To start with improving the insulation of the CookSaver a collage of some insulation examples was made (Figure 4.11) and their characteristics were pointed out.

Characteristics:

- the source of heat should be in direct contact with a very good insulating material (cork, wool)

- The insulation layer is made thicker to insulate better

- Air inclusions in small chambers
- Sandwich constructions

Figure 4.11: Collage and charateristics of inslating products.

Due to the insulating estimations for the concept is assumed that basically the CookSaver insulates well enough. Hence, the bottom and the closure between the lid and the basis are considered to be problematic.

Also the closure had to be ensured: the lid has to fit perfectly on the basis. To ensure the connection and maintain it during the cooking procedure, a small magnet is applied to the bottom side of the inner lid Figure 4.13). The magnet is strong enough to connect the two parts of the lid to not be opened easily. On the one hand this is important for safety on the other hand for the insulation effect. For example, young children should not be able to open the lid out of curiosity.

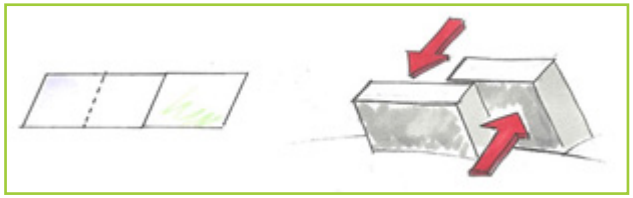


Figure 4.12:Collage and charateristics of inslating products.

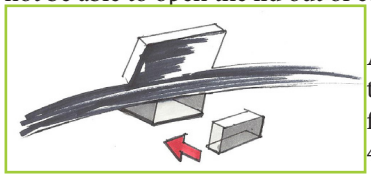


Figure 4.13 : Notch with magnet

Another improvement falls into the same line of thoughts. In order to be able to open the lid again the form of the upper handle had to be adjusted (Figure 4.12). Now, from two sides it can be pushed to solve the magnetic connection. Secondly, in order to improve the insulation at the bottom an extra layer of cork is added, which besides insulation, gives an healthy, eco-friendly impression.

4.3.3 Conclusion

Reconsidering the appearance and the structure some details are added and improved. In figure 4.7 a final drawing of the concept is represented. The structure can be seen in a section view in figure 4.10

4.4 Final design as 3D model

At this point, the appearance and the structure are known so a 3 D model is made. The final model can be seen in figure 4.14. The data of the model is included in Appendix CD H and its drawings in Appendix P-H. Using the model the feasibility and the stability could be controlled. The results are summed up in the following sections The data of weight and volume for the final cost calculation are taken from the 3D model.

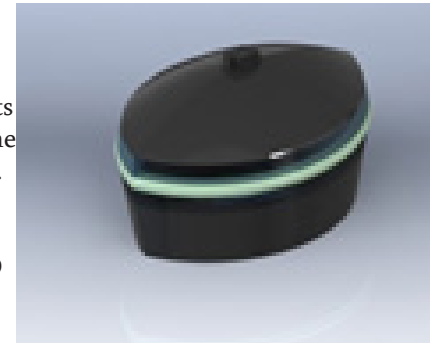


Figure 4.14: Final design as 3D model

4.4.1 Structural integrity

First, out of all parts an assembly was created to control the dimensions and make sure no interferences appear. After this was done and the model confirmed to be structural possible, all individual parts where controlled in reference to their problematic regions.

The model is represented in figure 4.15 in an exploded view. The basis consists of two shells which fit in each other. In the bottom of the inside shell five cork insulators around the sensor are placed. The placement is in chapter 5 explained. Above the shells a transparent ring, filled with Lumira® Aerogel is placed. Above this ring finally an enclosing ring is placed which ensures the stability of the structure. The lid part is symmetrically built up. It starts with the enclosing ring, followed by the aerogel ring and the two layers of the shell.

Figure 4.15: Exploded view

The parts which are considered to be problematic are the two shells of the basis and the ones of the lid. A thickness analyses was done based on the wall thickness of 2.5 mm to see where the structure is sensitive. As a limit 2 mm was used, so all parts which are thinner than 2 mm are colored.

The results are pictured blow (figure 4.16)

Figure 4.16: Probelmatic regions of diffrent components.

Green color means it is about 1,5 mm thick and red indicates a thickness lower than 1 mm. In reference to the mold it means the structure of the inside lid needs to be reconsidered and redesigned. This can be done by changing the radius of the curvature or enlarging the start and end thickness. The effects of enlarging the thickness (in correspondence to weight) are pictured (Figure 4.17).

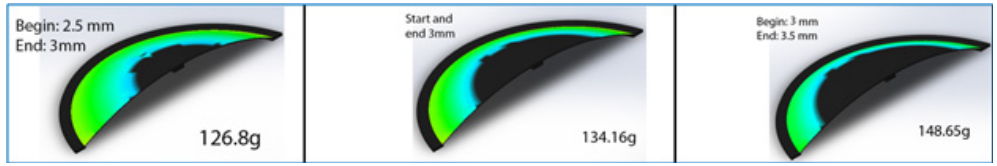


Figure 4.17: Improvement of the structure of the inner lid

Relative to the wall thickness the structural stability improves as well as the weight increases, but the transition between the curved and horizontal surface stays being problematic. Therefore the stiffeners which are now added to the outside lid will not be along the whole inner side of the outside lid but completed by stiffeners on the outer surface of the inner shell of the lid added on the problem surface.

4.4.2 Conclusion

The 3D model added some information about the structure and the feasibility of the concept. Furthermore are the weight, the surfaces and the dimensions defined. This values can, and need to be reused in the cost estimation as well as the energy saving calculations.

Actually, there remain some differences between the 3D model and the real design. The 3D model was among other made to build a prototype. The forms where oriented at the possibilities of the working space at the University. For example the notches are not included as well as the texture because it is difficult to realize.

Besides, the model can be used for further development. Injection molding simulations can be done or renders for promotion (compare figure 4.18).

Figure 4.18: The CookSaver in the kitchen

4.5 Insulation estimation

In the 3D model the dimensions of the final product are fixed. The thickness of the ABS material is reduced to reduce weight (compare Appendix P-H for more dimensions). The layer of air and Aerogel between the two "walls" is still the same as determined in the concept therefore it can be assumed that the insulation still is good enough. At this point it is look how good it is, theoretically. Also the insulating performance of air is compared with Aerogel and how its application it affects cost.
An interesting question from the company was if it would be reasonable to fill the entire space between the shells with Lumira®Aerogel particles. The calculations for the thermal conductivity, how much the Aerogel filling would cost and the insulating performance referred to in this section Appendix I.

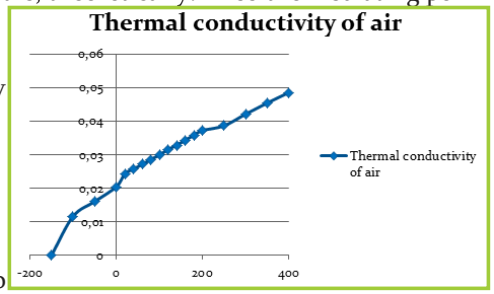


Figure 4.19: Thermal conductivity of air vs. temperature

4.5.1 Comparison Lumira ® Aerogel particles and air

First, the thermal conductivity of Lumira®Aerogel and air are compared. Both have an increased thermal conductivity at higher temperatures. At temperatures higher than 60 °C air is a better insulator than Aerogel whereas at lower temperatures there is little difference (figure 4.19 and 4.20). It is important to mention that this statement is only valid for motionless air without effects as convection taken into account .Moving air has a higher thermal convection. With experiments it needs to be proved if the air of the enclosed space in the basis and the lid is indeed motionless. If the air is moving Aerogel would be the better choice for insulation, because in this case, Aerogel has the lower heat conductivity. Further, filling the lid with Aerogel would cost 2.8 euro extra and filling the basis would cost 11 Euro extra. The insulating effect would be nearly the same as the one of motionless air.
If it is reasonable to insulate with Aerogel is discussed in the chapter 6 "Prototype and testing".

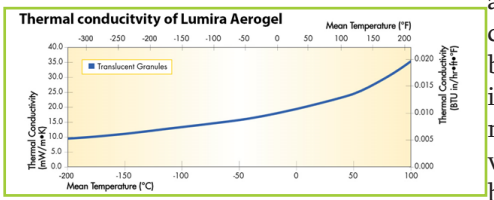


Figure 4.20: Thermal conductivity of aerogel vs. temperature

4.5.2 Main source of heat loss

At this point the theoretically heat loss of the CookSaver is calculated to get an impression about the expected heat loss and obtain a reference value for the testing in chapter 6. The heat flow is calculated and plotted against time to calculate the cooling time. Four calculations are done: One with the actual structure of the CookSaver, and a second one with a Lumira®Aerogel filling. They are repeated for a starting temperature of 116°C[4.2] for a pressure cooker . In chapter 6 the theoretical calculated values are controlled with tests.

Hence, the CookSaver is divided into three parts:
1) The lid: ABS (2.5mm)-Air/ Lumira®Aerogel (10mm)-ABS(2.5mm)
2) Aerogel layer: PC (2 mm)- Lumira®Aerogel (11 mm)-PC (2mm). Bottom
3) Bottom: Air (3mm)-ABS (2.5mm)-Air/ Lumira®Aerogel (10mm)-ABS(2.5)

The heat loss through the "Enclosing ring" is neglected due to its small surface. The calculations are explained in the following section and evaluated using Excel (Appendix I).

Assumptions:
- T_{env}=20°C
- T_0=100°C=273K
- A_1=0,057 m2
- A_2=0,013 m2
- A_3=0,14 m2
- k_{air}=0,0262W/(m*K) (motionless air)
- k_{aero}=0,03 W/(m*K)
- k_{ABS}=0,18 W/(m*K)
- k_{PC}=0,2 W/(m*K)
- Heat capacity: C=1,25*10⁴ J/(kg*K)

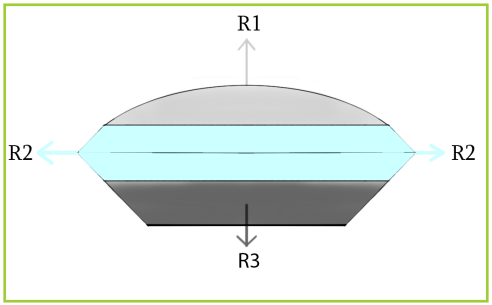


Figure 4.21: Model for the calculatios

Calculation:
I. The resistance of each part is calculated with the formula for heat resistance: Rtot=R_1+R_2+…, where R=l/(k*A). For example:

$$R_{1,air} = R_{ABS} + R_{air} + R_{ABS} = 2 * R_{ABS} + R_{air}$$

$$= 2 * \frac{0{,}0025m}{\frac{0{,}018W}{mK} * 0{,}057m^2} + \frac{0{,}01m}{\frac{0{,}0262W}{mK} * 0{,}057\ m^2}$$

$$= 2 * 0{,}244 + 6{,}696 = 7{,}2\ \frac{K}{W}$$

4.2: Value taken from: http://www.fissler.de/de/service/bedienung_und_pflege/schnellkochtopf_faq.html , FAQ (15/07/2013)

By this method the remaining resistances are calculated. In table 4.1 the results are presented

$R_{1,air}$	$R_{1,aero}$	R_2	$R_{3,air}$	$R_{3,aero}$
$7{,}2\ \frac{K}{W}$	$6{,}3\ \frac{K}{W}$	$32{,}3\ \frac{K}{W}$	$2{,}924\ \frac{K}{W}$	$7{,}37\ \frac{K}{W}$

Table 4.1: Resistance values of the different parts

II. With the single resistances the resistance for the entire CookSaver can be calculate with the rule for parallel resistances:
The same equation is used to compare the resistance of air and aerogel which gives for

$$\frac{1}{R_{tot,air}} = \frac{1}{R_{1,air}} + \frac{1}{R_2} * 2 + \frac{1}{R_{3,air}}$$

$$= \frac{1W}{7{,}2K} + \frac{1W}{32{,}3K} * 2 + \frac{1W}{2{,}924\,K} \rightarrow R_{tot,air} = 1{,}83\ \frac{W}{K}$$

$R_{tot,aero}$=1.78 W/K. The two resistances are plugged in Newton's cooling law:

$$T(t) = T_{env} + (T_0 - T_{env})e^{-\left(\frac{t}{RC}\right)}$$

Next, they are evaluated and plotted using excel. The calculated time for the water to decrease to reach 60°C are in table 4.2 and plotted in figure 4.22 and figure 4.23

	Cooling time for $R_{tot,air}$ (min)	Cooling time for $R_{tot,aero}$ (min)
T_0=100°C	266	258
T_0=116°C	335	326
Advantage	**69**	**68**

Table 4.2: Time to cool 2l water up to 60°C with and without a pressure cooker and with and without extra aerogel.

Conclusion:
Comparing the values of the cooling time with and without Lumira®Aerogel, it is obvious that the aerogel filling is not necessary if the air in between the shells is motionless. It means it is assumed there is no heat transfer of convection. The thermal constant of Lumira®Aerogel is slightly higher than the one of motionless air, but very close, as also can be seen in the figure 4.22 and 4.23. In chapter 6 it needs to be proofed.
Using a pressure pot instead of a normal pot stretches the cooling process for 1 hour,

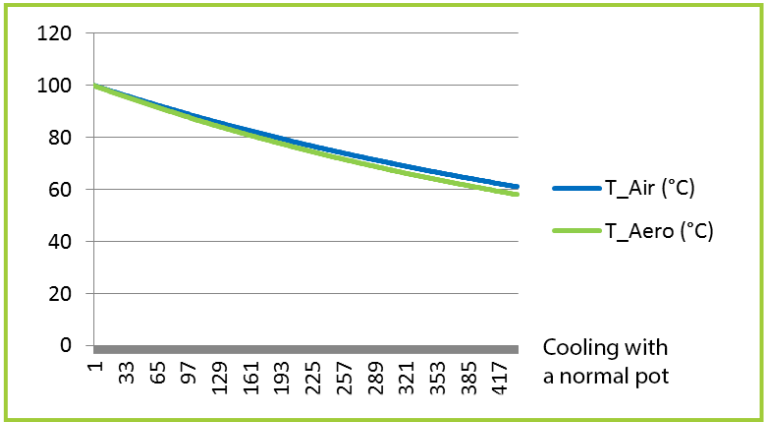


Figure 4..22 : Cooling with normal pot

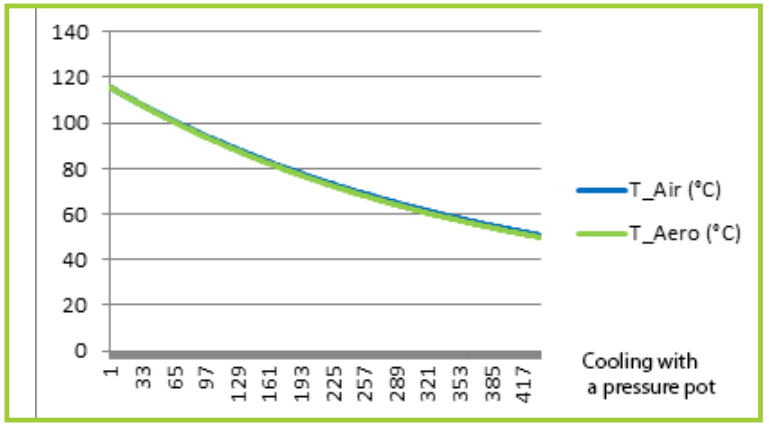


Figure 4.23 : Cooling with a pressure cooker

but considering the already long cooling time the pressure pot is not mandatory. It is not taken in consideration that at higher temperatures the food cooks faster as it is not important for the cooling process.
At last, looking at the respective R-values of the parts, the high R-value for the aerogel ring attracts attention. It is only based on the small surface of the ring and for testing it can be considered that the heat loss through the ring is negligible. Between the R value of the lid and the bottom there is also some difference as the surface of the bottom is nearly 2,5 times the one of the lid. Of course, the actual heat loss will be different because the heat at the inner surface of the lid and the bottom shell will not be a 100°C.
The values calculated above, also need to be validated by experiments.

4.6 Mass production

In this section an overview is given about the production of the single parts of the CookSaver as well as the assembling.

4.6.1 Production methods

In table 4.3 an overview is given of the manufacturing for mass production of the different parts. The weights are rounded off.

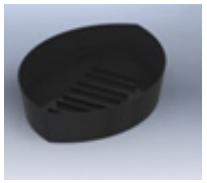
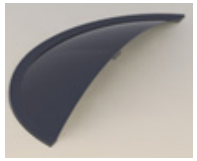
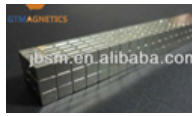
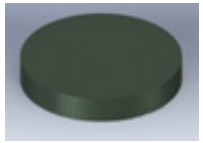
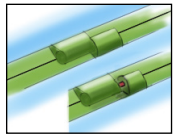
Nr.	Part name	Name	Specifics	Production method	Weight (g)
1	Bottom shell outside		2.5 mm wall thickness, material is high gloss ABS, at the bottom of the shell are stiffeners applied	Injection molding	497
2	Bottom shell inside		2.5 mm wall thickness, 1 mm at the bottom recesses for sensor and cork	Injection molding	457
3	First Aerogel ring		Consist of two PC parts with 2 mm wall thickness: A basis ring and an enclosing layer to form a hollow space to be filled with Lumira®Aerogel	Injection molding , cutting; Aerogel: Buying from Cabot	291
4	First enclosing ring		Hollow 5 mm high ring, low gloss, textured light green ABS	Injection molding	119
5	Second enclosing ring		5 mm high ring, low gloss, textured light green ABS	Injection molding same mold as nr 4, but side walls added	2* 60 =120g
6	Second Aerogel layer		Same structure as number 3	Ring: Same mold as nr 3 but side walls added; Aerogel: Buying in Cabot	292
7	Inside lid		From 3 up to 3,5 mm ABS, extra stiffeners added (not integrated in SW model for prototype)	Injection molding	152g *2 =304
8	Outside lid		2,5 mm ABS, extra stiffeners added at the inner side, handles included	Injection molding	91.96 *2 = 184
9	Magnet		Individual size and coatings	Buying from China, for example Alibaba.com	0,05 *2 =0,1
10	Sensor		Not buy-able as needed, consist of a metal housing with a pressure and temperature sensor	Buy from China	10
11	Cork plates			Bought in form or in plates and cut into the form	5*1,92 =10 g
12	Hinge		Integrated into molds, lid and basis can be cleaned separately. Not shown in 3D model.	Included in the injection molds of the enclosing rings	2* 10 g =20g

Table 4.3: Production methods of the parts

4.6.2 Assembling of the parts

Finally the assembling has great influence on the insulation: The parts need to be closed to hold the heat insight. To reach the goal, perfect insulation, precise manufacturing is necessary but also the use of silicone or adhesive would increase insulation as both works as a filling material for small chinks. The following section view in figure 4.24 demonstrates the chosen assembling method.

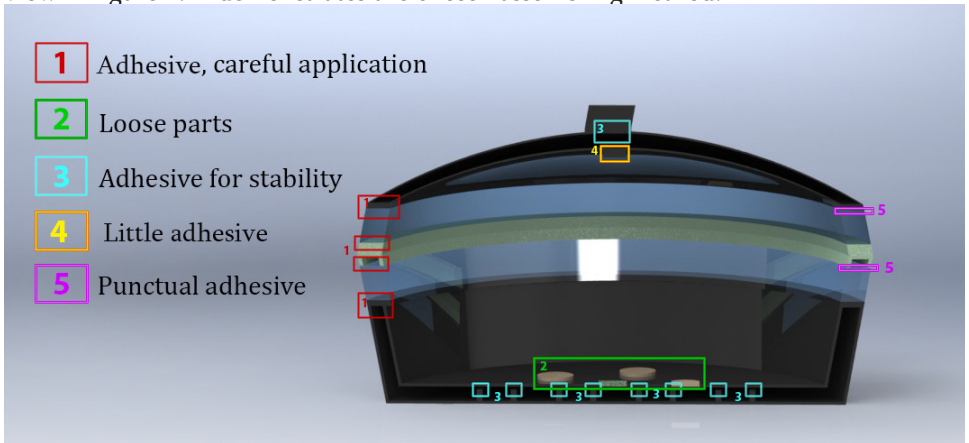


Figure 4.24 : Assembling methos for the CookSaver

Number 1, adhesive careful application indicates that two parts need to be connected with adhesive meanwhile it may not be visible at the outside. This assembling method is chosen because the adhesive fills every imperfection. It ensures that no warmed up air of the hollow space between the shells nor from the hot pot at the inside can escape.

Number 2, the loose parts, comprises the sensor and the cork disks. They are not fixed because they are more sensitive towards cleaning supplies than the rest of the materials. It simplifies the cleaning and increases the ease of use. Furthermore it is supposed that the sensor is the part most likely to be defect and the cork disk to wear fast out so. Hence, both of them need to be easy replaceable or repairable. To make it for children (as the target group are families) more difficult to get the parts out of its place little notches are renounced, but the whole product needs to be turned upside down. In a user test with the prototype it should be tested and user should be asked if they consider it good or would prefer notches.

Number 3, shows parts where the application of adhesive is necessary due to stability reasons, but it is not important how it looks like. It concerns the stiffeners at the inside of the shells.

Number 4, the magnet needs to fit into a special notch included into the injection mold of the inside shell of the lid. It can easily be fixed at the backside of the magnet with a little bit adhesive (figure 4.13).

Finally, **Number 5** points at the assembly of the Aerogel ring with the enclosing ones. Transparent adhesive needs to be applied on the upper surface of the Aerogel containing ring. This surface will not be wider than 2 mm, therefore it is called punctual adhesive.
To ensure the stability the enclosing ring on one side and the stable surface of the shell on the other one stick the ring to its position. As the ring has to be shaken while it is filled it has first to be open and closed after filling it with Lumira®Aerogel. The shaking procedure is necessary because Lumira®Aerogel consists of small particles which "need to find their place" to obtain the best insulation.
The advantages are that the aerogel is reusable and all parts can be easily separated and recycled at the end of the products life cycle.
The assembling procedure can be done in several parallel steps. The two shells of the basis, the lid and the Aerogel layer can be assembled at the same time and finally be merged. At last the enclosing ring with the hinge needs to be added and the cork and sensor disks set in.

4.7 Costs for mass production

After determining the production methods, the assembling methods and the detailed structure of the CookSaver the final cost estimation is performed. The detailed calculations can be found in Appendix CD-G.
In table 4.4the different cost factors and their contribution to the final cost price is presented.

Cost factor	Material (€)	Manufacturing (€)	Molds (€)	Final (€)
Cost:	12	5	7	24

Table 4.4 Contribution of the different cost factors

The least reliable values for the final price are the ones for cork and the sensors. They depend on quantity and difference between commercial and private buying price. It is assumed that the price will increase after testing the prototype and probably necessary adjustments are determined.
For manufacturing a price 50Euro/hour is assumed and 7 injection molds. This value is based on a first production line of 5000 products. The final production price would be around 24 Euros.

Comparable with the first estimation at the end of the concept development, which was 32 Euro, the production costs are about 8 Euros lower due to better material cost estimations and the material required is reduced to a minimum value. Although there is still room for improvement, probably the price will increase.

4.8. Conclusion of the detail development

A lot of information was obtained and integrated in this chapter. The main concept related changes are the ones of material and the re-development of the healthy appearance. The adjustment to the pressure pot played also an important role, because from this chapter on all changes had to be "pressure pot" proof. At last the concept is further developed for one, special pressure pot (illustrated in figure 4.3). The structure and its stability are improved. The ease of use is further developed with the fixing magnet and the integrated joint. Further with a 3D model it is insight given into the mass production methods and costs. It is assumed that the final production costs of the CookSaver are around 24 Euros. At the same time the model provides a basis for cost estimation and energy estimation. The model is also used to build a prototype.
The cooling time estimation yet shows that the performance of the CookSaver will be quite good, but still needs to be proofed. Remarkable is that the usage of Aerogel or a pressure pot does not mean immediately an improvement.

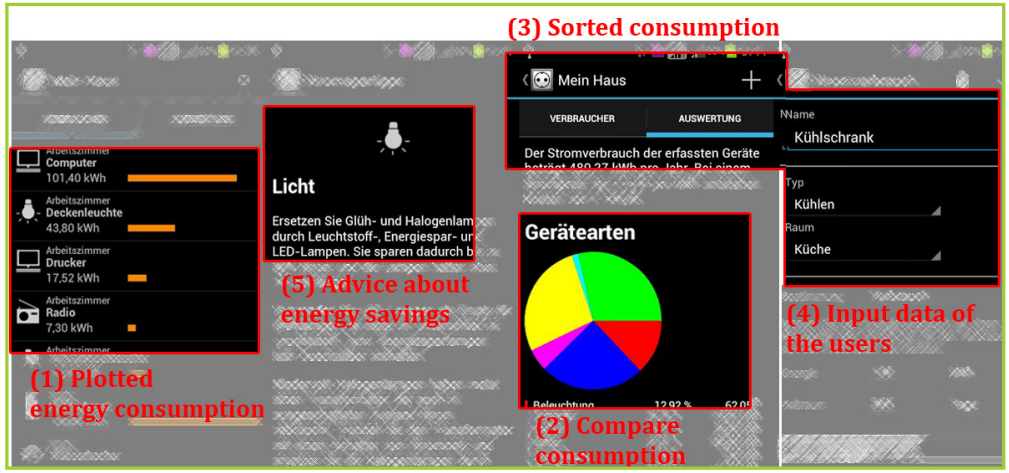


Figure 5.1: The important aspects of an energy saving related app

5. Interface with the "App"

The main part of the exercise is discussed and worked out, but it was pre-determined to develop an interface with the app. The interface itself and its coding will form another study project.
The goal was to establish a point of connection between the two projects. For that reason, a short market research is done and some questions in the survey referred to the usage of smart devices asked. The results are summed up in requirements and functions to establish the interface. Besides together with ComfortSavers it was stated at this point to reduce the necessary electronics to a minimum in order to lower the cost.

5.1 Trends of energy related apps

The market for smart devices is still growing and so there is an increasing market for related product providing a white range of applications (apps) fir these devices. Here, the focus is on energy saving related apps. To analyze these apps in figure 5.1 and example is given of a popular app to control the energy consumption in a household.[5.1]
The app calculates the energy consumption of the households' appliances and plots them (1) and compares their consumptions (2). The energy consumption can also be sorted by rooms (3). All these data needs to be given as input data by the user (4). Finally advices are given about how to save energy (5).
The energy savings become apparent as the users see where he wastes most energy. He can control the values of the households' appliances and immediately get insight how it affects the energy consumption. The delivered information increases the awareness towards energy consumption.
There are some parallels with the CookSaver. It needs also input data as, for example, the kind of food to be cooked. The app calculates the cooking time, cooling time and the resulting savings. The representation is also graphically, but for the development of the CookSaver it is more important to see which data he needs to deliver to obtain the highest functionality.
For instance, time is required as input. This can be done by the smart device. Second, the amount of food can be measured with a pressure sensor if the user gives as input data the kind of food. Of special interest is the temperature which cannot be measured from the outside. By seeing the temperature development over time the user gains insight into the cooking process.
Again referring to the example, the app should present the energy saving for each

5.1: Source: Google apps store on mobile phone version

kind of food graphically. So, the savings can be compared and the awareness of the users increases. Input data of the user is indispensable but needs to be complemented by input data of the CookSaver and a database. It may also not be forgotten, that referred to the target group analysis, the CookSaver should be able to send data to more than one device at the same time. The most common cellular connections are Bluetooth and WiFi. It would be a good addition if advice for the cooking behavior is given and, regarding to the history review in chapter 2, recipes provided.

5.2. Information obtained from the survey

A few questions were asked to form the bridge between the kitchen device to be designed and the future interface. Only the data which brings new requirements up will be discussed at this point. It is possible to take more conclusions of the asked questions but that is for the further development by ComfortSavers.

At the beginning, the question is whether someone has a smart device and with which operative system it works.
59,7% of all respondents have a smartphone so there are enough respondents to consider the data reliable. Most of them have an android or mac based operative system. The future kitchen device should therefore work on both of them. Remembering the competitor analysis in section 2.4 it will be an advantage.
Secondly, all respondents are asked in which kind of information they are interested while cooking. Most of the answers are part of the "calculations" of the app or graphic related. It is only of special interest, that respondents with children are very interested in the temperature of the meal then those without children. So, measuring the temperature is not only interesting out of safety reasons, as pointed out in section 2.2, but also for the customer. It means the future kitchen device should measure the temperature of the food.

Out of general interest, it is asked whether respondents know hay boxes. Analyzing the data about energy under the constraint, the respondents know hay boxes and it seems they are more interested if they are familiar with the concept. It could therefore be helpful if a link is made to traditional aspects of the kitchen device.

Interfaces between "hardware" parts-modular N2 digram

Environment			Database with information about cooking times of different kinds of food	Provides recipes, Provide additional information to increase awareness towards energy consumption	
Recipes, energy saving	**User**		Calibration of weight	Kind of food Local energy costs	
		Cooksaver	Amount of food, Temperature		
			Smart Device	Calculate energy savings, Calculate total cooking time, Calculate money savings Keep up temperature	
	Choice of food			**Interface of smart device**	- alarm if the temperature is below 60 degrees, - Alarm food ready - Energy savings - Cost savings - Cooking time - Recipes - Additional information - Temperature of the meal

Figure 5.2: N2 diagram with mdular interfaces

5.3 Requirements and functions of the app

The information found is summed up in a list of requirements and functions the CookSaver has to fulfill to create the interface.

Requirements
The CookSaver should be able to send data with a Bluetooth or WiFi connection
The CookSaver should be able to send data to 2 devices at the same time
Electronic parts must either be liquid resistant or not come in contact with it
The CookSaver should measure the temperature
The CookSaver should be able to measure the pressure of a (filled) cooking pot

Functions:
F1: The CookSaver must send data in a format to be worked out of Android or Mac operating system, as a wish:
The kitchen device should be able to measure

5.4 Developing the interface

First of all a distinction between the functions and the requirements has to be done before establishing a data flow diagram. The functions are used to make a modular N2 chart (Appendix CD- and Figure 5.2)[5.1] to establish the interfaces between the user, the enviroment, the CookSaver, the Smart Device and what finally can be seen on the interface. Using the obtained interfaces between the components a data flow diagram was made (figure 5.2)

The CookSaver is determined to have a temperature and a weight/pressure sensor. Both data is necessary to calculate the final cooking time, which the user would like

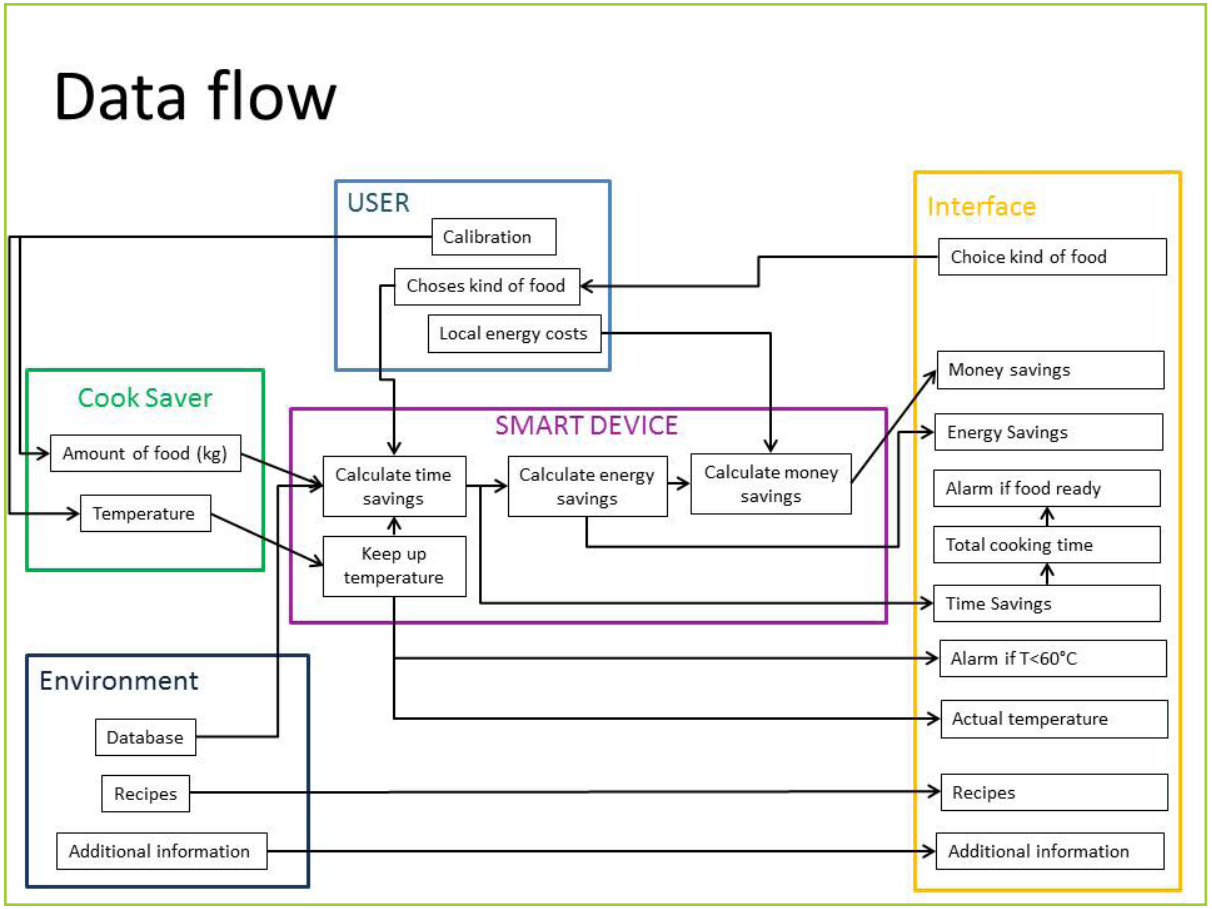


Figure 5.2: Data flow diagram to illustrate the interfaces

to know and estimate energy savings.
To make the device smarter it the measurement starts automatically when a sudden increment of temperature and pressure is recorded. The user does not define a start moment.
Hence, the Smart device needs to perform the calculations for energy saved money saved. Also he needs to keep the time and the temperature up to date. The required data, as cooking times for hay boxes and energy prices, comes from the an data base (placed in the "Environment") and the user. The final results are presented on the screen of the smart device.

The sensors are identified so the following step is to determine the placement. Important is a distinction between the final product and the prototype. It is an aim that the prototype is as close as possible to the real product so in first instance the placement and choice of sensors in the real product is done and second, it is looked if it also can be put into practice for the prototype.
A very important requirement for the sensor is its equality and stability of measurement, no matter which kind of pot is placed in the CookSaver. Therefore it is chosen to place a small circuit board including a weight sensor, a temperature sensor and a wireless transmitter in a small metal box in the center of the bottom of the CookSaver. The cork plate is reduced to five supporting points. The placement as well as the new section view of the bottom is illustrated in figure 5.2. By placing the sensor in the middle of the bottom it is ensured that it will always be in contact with the cooking pot. Further the metal box transmits the heat very well to the temperature sensor.

As a special box is necessary for the final product it cannot be installed in the prototype. It is possible to work with the cork plates and then place a non-wireless temperature sensor on the bottom of the cooking pot. This can be connected to a computer to take the measurements.

5.1 Definition N2-diagram: The N 2 chart, also referred to as N 2 diagram, N-squared diagram or N-squared chart, is a diagram in the shape of a matrix, representing functional or physical interfaces between system elements. It is used to systematically identify, define, tabulate, design, and analyze functional and physical interfaces. It applies to system interfaces and hardware and/or software interfaces
Source: http://en.wikipedia.org/wiki/N2_chart, 20-7-2013)

6. Prototype and testing

As mentioned earlier, testing was necessary to prove the theoretical calculations and inform about the final performance of the CookSaver.

For testing purposes, but also marketing ones, a prototype is made. It was determined that the prototype should be as close as possible to the real design. It means the bottom and the lid are made double walled out of ABS (figure 6.1), and the Aerogel ring is made of PC en filled with Lumira®Aerogel particles.

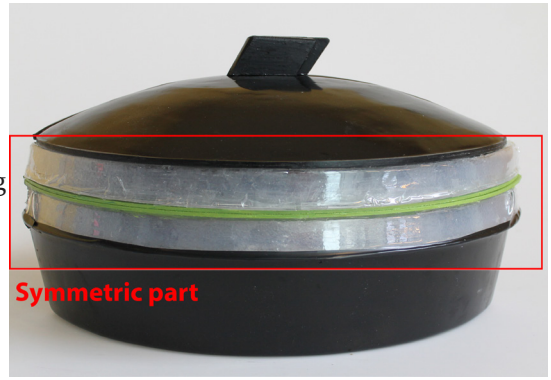


Figure 6.2: Symmetric part vor the CookSaver

6.1 The prototype

Figure 6.1: Two shells of the CookSaver

A few adjustments aer done for the prototyping: The bottom and the lid part are build up symmetrically (figure 6.2) in order to use the same mould and fit the pressure cooker inside (figure 6.3). The model is about 20 mm wider than the original design. At last, and that is the main change, due to the symmetrical construction the handles of every pot (also figure 6.3) fall entirely into the CookSaver. However this is not the intention. Figure 6.4 demonstrates based on a normal pot how the real proportions of the CookSaver are. Further it was resigned to implement the magnet and the joint to maintain the flexibility of the parts. As it is a hand made prototype the parts do not fit perfectly to each other, but can be moved to its place. Any imperfections are filled with silicone and adhesive. The white particles which can be seen in figure 6.2 in the Aerogel ring are Aerogel particles who reacted with the silicone. In figure 6.5, 6.6 and 6.7 impressions of the prototype are given.

Figure 6.3: The pressure pots fits very closed into the CookSaver

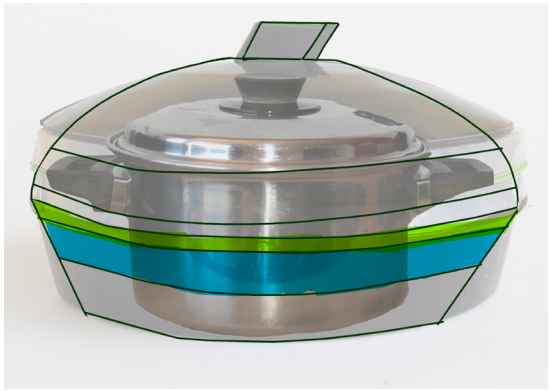


Figure 6.4 The CookSaver with a normal pot and its real proportions

Figure 6.5:The protoype

Figure 6.6:The protoype woth opend lid and pressure cooker

Figure 6.7:The baiss including cork plates

6.2 Test arrangement and execution

In this section the theory, circumstances, assumptions, and execution of the testing is described.

Theory and circumstances: The temperature of the cooking pot is measured with a thermocouple. A thermocouple consists of two wires of different metals which are connected at the end. One wire is connected to a "cold"reference point and the second one with the "hot"place to be measured. The temperature difference induces an electric voltage which can be measured and translated into a temperature. As the temperature of the pot declines the voltage changes and so does the temperature.
The thermo couple is applied to the outside wall of the pot. It is assumed that the temperature is nearly the same as at the inside due to the high thermal conductivity of the metal pot. The thermo couple is on one side connected to the cooking pot, on the other one with a computer. The computer collects the voltages with a frequency of 1000Hz over 30 minutes and transfers them into temperature. The frequency of 1000Hz is very high, but chosen to prevent the influence of noise. This data can be smoothed, as explained in the following section.

Execution: Each frequency of the testing process begins with cooking 2l water until its boiling point. When the water boils the heating is turned off and the pot placed on a prepared testing surrounding (Figure 6.5) where the measurement of the temperature starts.
Basically four measurements are done. First the temperature development of a normal pot and a pressure pot are measured over half an hour without the CookSaver.
Second the measurements are repeated for a normal and a pressure pot with the CookSaver as insulation. The gap between the lid is extra insulated with insulation tape.
In this case a T-couple is used with the environmental temperature as reference. Is

Figure 6.8: Test execution

is measured at the begin of the testing to be 25°C . The final results of the testing are four lists with measure point (s) vs. temperature, to be found in Appendix CD-K.
During the test some observations were made which need to be mentioned:

- Within the CookSaver develops pressure
- At the inside occurs surface moisture when cooking with an normal pot
- The lid and the bottom become clearly warmer

The first and third observations are mainly important. Yet it was not considered that pressure develops at the inside of the CookSaver due to the expansion of the heating air. On the one hand, this could be dangerous, on the other hand it makes the re-opening of the CookSaver difficult if a strong magnet holds the lid closed.
For testing it was not a problem as there was no magnet nor is the prototype entirely closed, but for the final product a gas exhaust it will be necessary to let the hot air out.

Another goal of the test was to be able to give a recommendation if additional insulation is necessary. The temperature development at different points is not measured but by touching the CookSaver it yet becomes clear that mainly the lid and the bottom becomes hotter. The assumption that this would happen was already stated in Chapter 3.4, the concept evaluation. At this point it confirmed. The calculations will show if extra insulation is encessary.

The second obervation neither considered in the design development, but does not form a problem. As stated in the program of requirements the material should be resistant against liquids the moisture at the inside does not damage the CooKSaver.

6.3 Evaluating the measurements

The objective of the testing is to obtain the resistance constant of the CookSaver to compare it with the theoretical calculations and obtain a factor of cooling.
This factor shall be used to compare the effect of the CookSaver, but also the one of a normal pot and pressure pot are compared. The "raw data" is added in Appendix

CD-K.
First a global view at the data is done to see what can be expected of the calculations. In figure 6.9 and 6.10 the measurements with and without CookSaver are restrictively for a normal and a pressure pot illustrated. In figure 6.11 a plot of all measurements is given.

The maximum value is determined as 100°C and the minimum as 60°C. The temperature development over 30 minutes (1800 seconds) is illustrated.

Immediately it comes to mind that the CookSaver clearly has an effect on the temperature development. The final temperature after half an hour is for both, the normal pot and the pressure pot, approximately 6°C higher with the CookSaver. In table 6.1 the values of temperature after 3o minutes with the usage of a CookSaver are compared with the theoretically calculated ones . The theoretical start temperature is assumed to be the same as the one of the experiments (Appendix CD-I).

CookSaver used:	**Normal pot**	**Pressure pot**
Theoretical:	81	76

Table 6.1: Temperature of the cooked water after 30 minuts

Measured:	80	76

The theoretical temperature and the calculated ones are nearly the same.
It was no expected that the prototype insulates as well as the assumed, industrial manufactured product one be. Apparently it is good enough to obtain representative values.
Looking at the results it can be stated as confirmed that the air in between the shells is motionless as assumed for the theoretical calculations. Filling them with Aerogel particles would not improve the insulation.
Further test should be done to measure the temperature development over a longer time to confirm these values as representative.
As explained, the temperatures are taken at the outside of the pot.
Hence, theoretically the temperature of a pressure pot should be higher than for a normal pot as the inside temperature is higher. An explication for the lower value could be that the wall of the pressure cooker is better insulated that the ones of a normal pot. A mistake of the measurements can be barred as the measurement are taken twice and leaded to the same result. The measurement should be repeated by taken the temperature at the inside of the pot.

Noticeable is also that the begin temperature is not 100°C/116°C but about 85°C/80°C.
Apparently the pot with the cooking water cools at the begin very fast
(due to the exponential cooling low) and until it is placed in the CookSaver it reached 85°C. Taking this as a starting value the temperature would be after 186 minuets or 3.1

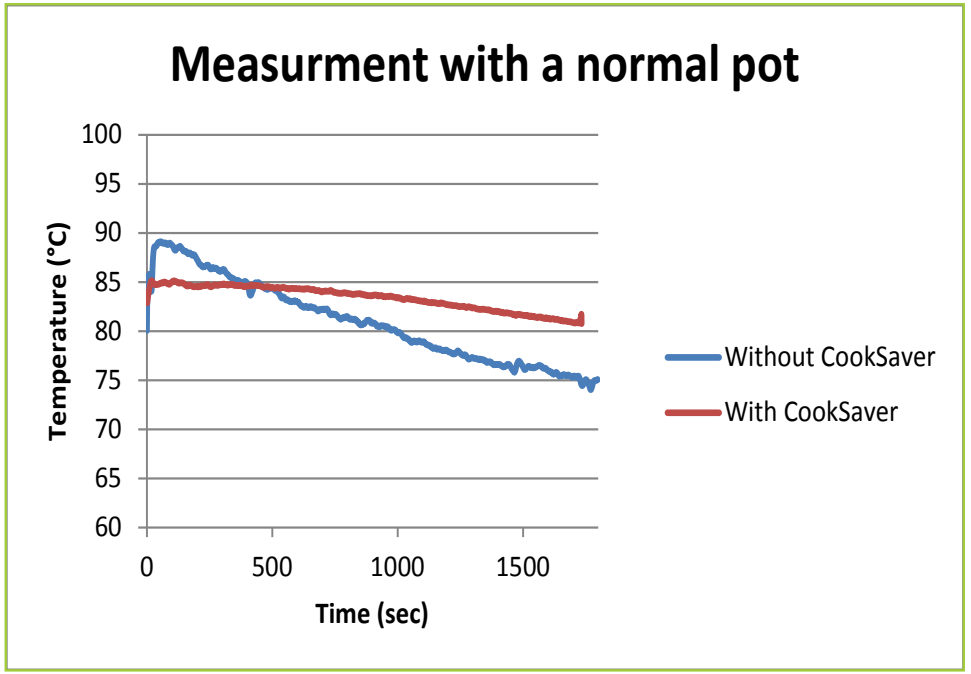


Figure 6.9: Plotted data of the measurements of a normal pot

hours below 60°C for a normal pot. Compared with the 266 minutes (4.4 hours) theroretical calclculated ones using a begin temperture of 100°C it is quite lower than expected but still considered well enough for cooking a meal referring to the old cooking books.
After the global comparison of the graphics, the obtained values are used to determine the resistance of the CookSaver. Regarding the results it should be close to the theoretically calculated one of 1.83 W/K. For calculations Newtons Coolings law is retyped:

$$R = ln(\frac{T(t) - T_{env}}{T_0 - T_{env}})^{-1} * \frac{t}{C}$$

T_{env}=25°C was measured and C=1.25*10⁴J/(kgK.)
For T_o the value of a normal pot after 300 seconds is taken and for T(t) after 1500 seconds. It means t=1500-300=1200. It is assumed that after 5 minutes the first warming up effects are passed and, regarding to figure 6.9, and after 1500 seconds a notable decrease is measure.

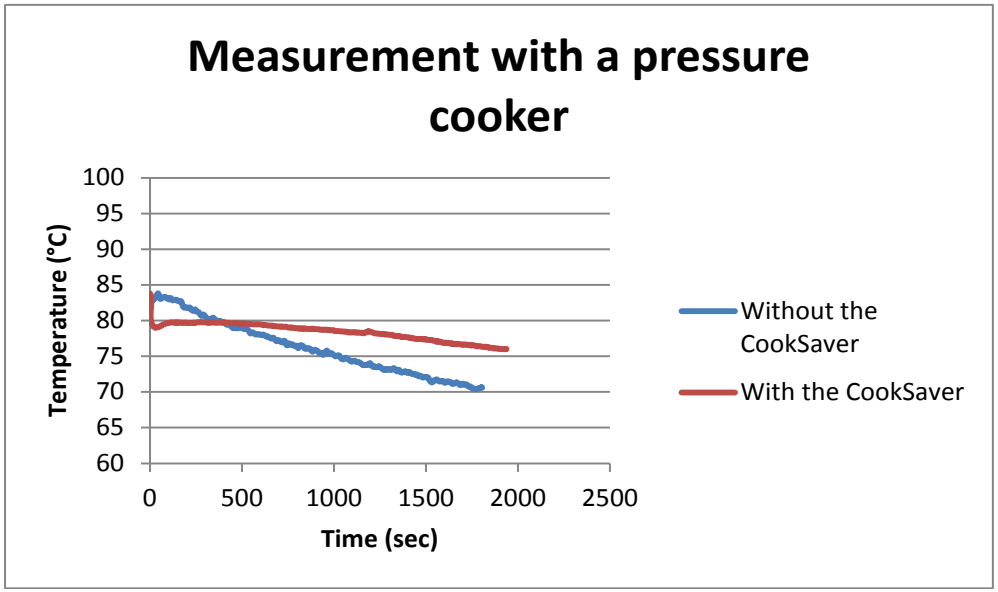


Figure 6.10: Plotted data of the measurements of a pressure cooker

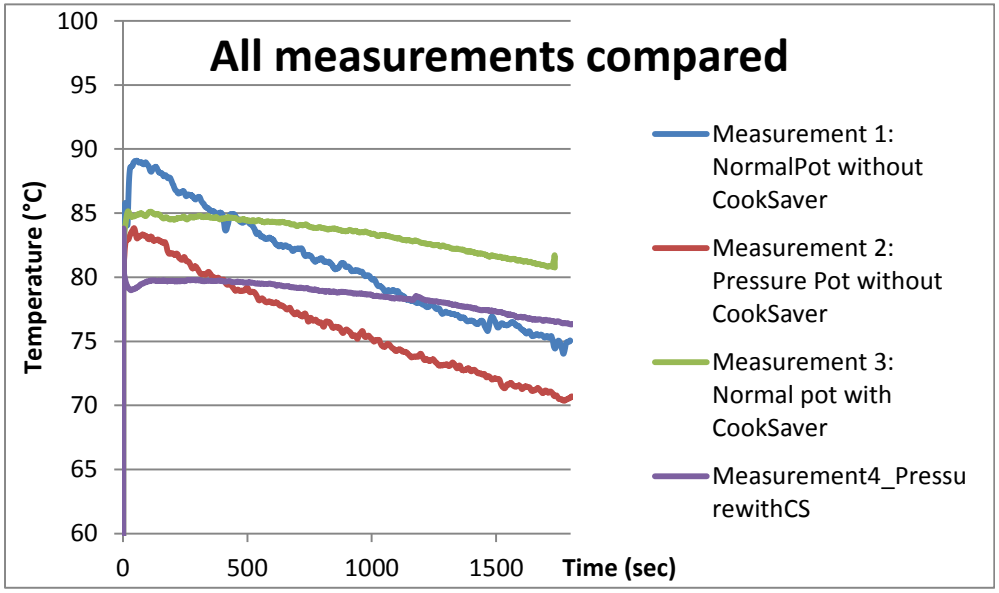


Figure 6.11: Plotted data of tall measurements

The values are

T_0= 84.7 °C
T(1200)= 81.6°C
T_{env}=25°C

Setting into the equation:

$$R = \left| ln(\frac{81.6-25}{84.7-25})^{-1} * \frac{1200}{1.25*10\text{^}4} \right| = 1.758 W/K$$

As expected the R value is very close to the one of the theoretical calculated one which confirms the satstement that it is reasonable to assume standing air and the effects of convection within the CookSaver are negligible. However, the mesurements should be repeated and the R value calculated over a longer periode of time.
In figure 6.9,6.10.6.11 the decreasing curve is yet not visible very well. The side effects of wariming the CookSaver up are assumed to happenw ithin the first 5 minuts,

but it should be controlled.

6.4 Conclusion

The test give a first impression of the performance of the CookSaver. Clearly with the CookSaver has an insulating effect of approximately 6°C/half hour. The resistance value is very closed to the theoretically calculated one, but further test over a longer time should confirm these values. The prototype has proofed that the air in between the shell can be assumed to be motionless and an extra insulation with Aerogel would not improve the performance. Althrough adding extra insulationin form of Aerogel, Bluedec® or another insulation material to the lid and the bottom would improve the performance.
It is recommended to repeat the measurement for the pressure pot with a sensor inside the pot. Now, no conclusion can be give if the CookSaver does work better with a Pressure pot or does not.
However, there are many more things to be tested. For example, the effect of aluminium foil or just another color at the inside or with extra insulation at the lid is of interest.
Also tests with food need to be done, which can be realized with the old recipes described in section 2.1. It is recommended to do test with a higher number of recipes to get insight into the working of the CookSaver.
Finally it is a recommendation for the final product to implement a pressure gas exhaust and improve the insulation of the bottom and the lid, before using the prototype for further measurements the adhesive should be renewed as it proofed not to be heat resistant.

7. Conclusion and recommendations

At this point a short review of the project development and its results is given as well as some recommendations for further development.

At the begin the analysis delivered very useful information about the target group, the market situation and the needs of the customer.
Hence, mainly the design requirements stated in the analysis are not reflected in the final design. It is rather questionable if the design is seen as healthy.
The materials are of low contrast as mainly plastic is used .Black is not the color which is seen as healthy, but well fitting to every kitchen.
The materials are used to reach the goal of a maximum price of 50 Euro, but it should taken in consideration to use different materials and increase the price.
It is recommended, if the final cost price permits it, to make the enclosing ring of wood and ensure the insulation with a rubber layer to increase the contrast. This would increase the attractiveness of the CookSaver for the customer.

A user test should be done where a n umber of possible customers are asked what they prefer. It should be taken caution that the asked persons represent the whole target group. The survey mainly represented young people without children.

Comparing the final performance of the CookSaver to keep a meal approximately 2 hours warm and save about 60% energy it can compete with the products on the market. The main difference is that the CookSaver is cheaper and hence more affordable .

The detailed development can also be changed. For the measurements quite big pots are used. It is assumed if using a smaller pot more convection happens and the insulating performance decreases. In this case, the free space of the CookSaver should be filled if possible. In the detailed development some examples are given about existing insulation methods, but there could be taken more information out.
The observation of the testings yet added two new details. A gas exhaust should be added for the developing pressure an rubber ring on the enclosing ring and for in between the two parts of the lid. These were the places which needed extra insulation in the prototype
Finally the test shows that the CookSaver works but there is still room for improvement. There a re still a lot of possibilities to test and improve the insulating effect.
The information given in this record should be seen as a basis for further development. Before beginning with next a next series of test the adhesive of the prototype should be renewed. It needs to be taken caution because the used materials have a maximum service temperature around 100°C and hold not come in contact with the cooking pot.

Regarding to the app , it would form a great addition to help the customer to understand and get insight into the functionality of the CookSaver. For further development the results of the survey should be regarded,

Above all, it can be stated that the goal to develop a modern energy saving product, based on the principle of hay boxes, for use in the kitchen is reached. The interface with the app is established by adding the required sensors and integrating them into the design of the CookSaver.

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9. Overview Appendix

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Appendix C- Energy savings calculations
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Appendix J- N2 diagram
Appendix K- Raw data of the measurements

Printed

Appendix A- Results survey
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Appendix F- Concept development and concept dimensions

Other deliverables

Protoype and remaining material for ComfortSavers